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Assessment of the Northern Shrimp Fishery from Northeastern Newfoundland to Southern Davis Strait (Divisions 3K to 0B)

by

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ABSTRACT

The status of northern shrimp resources from northeastern Newfoundland to southern Baffin Island is reviewed. The assessments are performed by fishing area and current TAC's and catch levels are evaluated based on fishery performance, survey and biological sampling data. The data base is thoroughly investigated in an attempt to detect fishery effects.

RÉSUMÉ

On examine l'état des stocks de crevette nordique par zone de pêche, depuis le nord-est de Terre-Neuve jusqu'au sud de l'île de Baffin, les TPA et niveaux de prises étant évalués d'après le rendement de la pêche ainsi que les données des campagnes d'évaluation et de l'échantillonnage biologique. On étudie à fond la base de données dans le but de déterminer les effets de la pêche.

INTRODUCTION

The management plan for northern shrimp from May 1, 1990 to April 30, 1991 (the fishing year) remained the same as in 1989/90. TAC's totalled 26,400 t, including 7520 t in NAFO Subarea 0+1. Over 20,000 t were taken by mid March, at which time effort was restricted to the southernmost grounds. Other areas were either ice-covered or EA's had been reached.

The fishery, which started in the late 1970's, declined during the 1980 - 85 period. Low effort levels at that time were attributed to poor economic conditions. The subsequent expansion since 1986 was due, primarily, to two reasons. First, market acceptability of the small "industrial" grade shrimp increased substantially in 1986 and, second, new areas were fished at various seasons of the year when shrimp concentrations were high. Thus, total catches increased from less than 2000 t in 1985 to over 20,000 t for the past three years.

This paper provides a detailed review and analysis of the existing research and commercial fishery data for shrimp ranging from Division 0B in the north to Division 3K in the south (Fig. 1), including ten fishing areas and two species. The assessment is focused on detecting the effects of past fishing practices (or lack thereof) on the resource.

METHODS AND MATERIALS

Data were available from both the commercial fishery and research vessel surveys, the amount for each area varying with the number of years of fishing activity and the number of surveys. Catch and effort data are provided for each area and catch per unit effort (CPUE) calculated by month and year. Standardization of catch rates by multiple regression was attempted for three areas whereas raw catch and effort data were used for the remainder. Comparisons were made between catch and effort and CPUE and effort. The commercial catches at length were constructed by year and compared with the abundance at length from the research surveys (where available) to evaluate recruitment patterns and changes in size and proportions of the female component. Research survey biomass estimates were compared with catch and CPUE and proportions of maturity stages were calculated from survey data from 1986 onward. Biomass estimates of shrimp were also compared with those for cod and Greenland halibut.

Because of the large amount of data involved in this review, the results of the assessment are presented in tabular form with reference to relevant tables and figures (attached). This type of presentation was chosen as the most effective means of including all important information without being overly verbose. The results section is followed by a discussion which summarizes the findings for each area.

ASSESSMENT RESULTS

SUMMARY TABLE

	HOPEDALE	CARTWRIGHT	HAWKE	DIV.2G	DIV.0B
TAC(90)	4400t	1600t	2000t	2580t	3500t
RECENT CATCHES	4600t(86-90) (Fig. 2, Table 1)	1450t(86-90) (Fig.12, Table 4)	2300t(87-90) (Fig.20, Table 7)	2600t(88-90) (Table 10)	2500t(88-90) (Table 11)
CPUE	Stable (86-90) Decrease (77-83) (Fig. 3, Table 1)	Decrease (77-85) Big increase (86-90) (Table 4)	High-increasing 87-90 (Table 7)	High 88, lower and similar 89,90. (Table 10)	High 88, low 89 and high 90. (Table 11)
LENGTH FREQS.	Females abundant. Size of females variable but no trend. Recruitment appears stable - no strong/weak year classes. (Fig. 4)	Females abundant. Female size: no trend. Regular recruitment - no strong/weak year classes evident. (Fig.13)	Percent females high in survey & catch data (88-89). No strong/weak year classes evident. Size of females increasing (81-89).(Fig.21)	Higher proportion males in 1989. Female size constant.(Fig.25)	More small animals in 89 but could be related to change in area fished (farther south). (Fig.27)
BIOMASS	Decline 79-81 Variable 81-90 (catches before survey added). (Fig. 5, Table 2)	Variable-big increase 86-88 (immigration?). (Fig.14, Table 5)	Big increase 88. Decline since (immigration/ emigration?). (Fig.23a, Table 8)	No data	No data
MATURITY STAGES	Proportions consistent 86-90. (Table 3)	Proportions similar 86-88. (Table 6)	Proportions similar 88-90. (Table 9)	Not available	Not available
COMPAR-ISONS	-Catch vs. effort: linear and positive. (Fig. 6) -CPUE vs. effort: no relationship.(Fig. 7) -% females (i+1) vs catch: negative.(Fig. 8) -CPUE vs. biomass: no agreement.(Fig. 9) -Biomass (i+1) vs catch: negative(weak).(Fig.10) -Biomass vs. fish: inconclusive.(Fig.11)	-Catch vs. effort: flat.(Fig.15) -CPUE vs. effort: negative but the position of points illogical.(Fig.16) -CPUE vs. biomass: no agreement.(Fig.17) -Biomass (i+1) vs catch: inconclusive.(Fig.18) -Biomass vs. fish: inconclusive.(Fig.19)	-Catch vs. effort: increasing.(Fig.22) -CPUE vs. effort: inconclusive.(Fig.22) -CPUE vs. biomass: no agreement.(Fig.23b) -Biomass vs. fish: positive, if anything. (Fig.24)	-More fishing effort in south in 89-90. Could account for differences in CPUE and len/freqs. (Fig.26)	-More fishery in the southern areas in 89-90.(Fig.28)

SUMMARY TABLE (CONT'D.)

	ST.ANTHONY BASIN	FUNK ISLAND DEEP	EAST ST.ANTHONY BASIN	HUDSON STRAIT & UNGAVA BAY
TAC(90)	1600t	1500t	500t	1200t
RECENT CATCHES	1100t (87-90) (Table 12)	1800t (88-90) (Table 14)	1100t (88-90) (Table 15)	800t (86-90) 1200t (87-89) (Table 16/17)
CPUE	Increasing (Table 12)	High 88, lower but similar (89-90). (Table 14)	Stable (Table 15)	Highly influenced by very dense concentrations. (Table 16/17)
LENGTH FREQS.	Higher % males 87 and esp. 90. (Fig.29)	Increasing % males 88-90.(Fig.30)	Increasing % males especially in 1990. (Fig.31)	Size of females declined 79-86. (Fig.33/34)
BIOMASS	Old data. Increase 84 to 85.(Table 13)	No data	No data	None reliable
MATURITY STAGES	Not available	No data	No data	Not available
COMPARISONS	-Biomass vs fish: inconclusive. (Table 13)		-Area fished in winter/spring. -High but variable catch rates each year.(Fig.32)	Pandalus montagui

DISCUSSION

HOPEDALE CHANNEL

The Hopedale Channel is the area fished most extensively since the northern shrimp fishery began in the mid to late 1970's. Annual effort levels have covered a fairly broad range, from less than 2500 (unstandardized) hours to more than 12,000 hours fished. Consequently, catches have fluctuated from about 700 tons to more than 6500 tons. Yet within this range of exploitation, significant effects of fishing are not evident from the commercial and research data bases. Catch increases in a linear fashion with effort. There is no relationship between catch per unit effort (CPUE) and effort, certainly not a negative one. Commercial length frequency distributions (LFD's) show variability between years but no trends that can be related to patterns of fishing. Proportions of females in the commercial catches are also variable and unrelated to the catch levels. Recruitment appears to be regular and there is no large variation in year class strength. Although the LFD's from surveys support the findings from the commercial data, the two abundance indices (commercial CPUE and research biomass estimates) show no relationship. The only suggestion of a fishery effect is a loose association between catch in a given year and the biomass estimate for the next year. Predator/prey effects cannot be demonstrated with the current data base. Very low or negative fishing mortalities implied from survey data show that much of the observed variation between years is due to changes in availability rather than abundance.

Catch rates (both unstandardized and standardized) have remained stable over the past five years and the high catch of 6500 tons in 1988 apparently has had no discernable adverse effect on the resource in this area. Declining biomass estimates over the same period are more difficult to interpret because of the abundance - availability question. Given the maintenance of a spawning biomass in a fishery targeted toward that component of the resource, the regularity of recruitment and the lack of any other negative biological indicators (e.g. high proportions of primiparous females, change in age at sex inversion), it is concluded that the resource is healthy and that some increase in annual removals might be considered. Therefore, the TAC for the next 2 - 3 years could be increased from 4400 tons to about 5000 t to see how and if the resource reacts to a higher level of exploitation.

CARTWRIGHT CHANNEL

After its inception in the late 1970's, the northern shrimp fishery in Cartwright Channel was virtually non-existent from 1980 to 1985. Interest was renewed in the area with the improved market conditions of 1986, which are reflected in the commercial

and research LFD's. Effort levels range from just a few hours fished (unstandardized) in the mid 1980's to almost 4000 in 1979. Catches ranged from 2 or 3 tons in the low effort period to over 1600 t in 1989 and 1990. The data examined to detect effects of fishing are inconclusive, sometimes suggesting responses to fishing, other times not. Plots of catch and effort suggest that catch does not increase at effort levels beyond 1500 hours (unstandardized or standardized). For effort greater than 1000 hours, there is a clear decrease in CPUE with increasing effort. On the other hand, it is difficult to visualize this relationship in the general production perspective because it is illogical to have the 1987 point in the lower right of the plot of CPUE against effort and the 1988 in the upper left. CPUE's are, on average, higher from 1986 to 1990 than they were in the late 1970's when the fishery began.

LFD's, as for the Hopedale Channel, show fairly stable recruitment with no obviously strong or weak year classes. The proportions of females are variable but, again, cannot be related to fishing practices. Research LFD's showed higher proportions of smaller shrimp than the commercial data, particularly for modes around 11 - 13 mm and 14 - 16 mm. The size and shape of the female mode was in good agreement for most of the comparisons made between the two data sets. Commercial CPUE's and research biomass estimates showed no relationship and the catch level in a given year had no apparent effect on the survey density the following year. Predator/prey relationships could not be defined and negative fishing mortalities between 1986 and 1988 suggest immigration.

Overall, the area has shown signs of instability, likely due to immigration/emigration. Biomass estimates decreased between 1980 and 1983 but increased sharply from 1986 to 1988. Negative mortality rates are biologically impossible. On the positive side, there appears to be no major concerns regarding recruitment or the spawning biomass and there has been no evidence of a change in size or age at sex inversion. TAC's of 1600 tons have only been in place for two years. Also, since the fishery has been rejuvenated, the seasonality has completely changed from summer/fall to spring/summer. Given these factors, it would be prudent to maintain the 1600 ton TAC for the next 2 to 3 years to see how the resource responds to that level of exploitation.

HAWKE CHANNEL

The Hawke Channel was the first area fished for northern shrimp on an experimental basis in the mid 1970's. However, the fishery actually developed farther north in the Cartwright and Hopedale areas. It was not until 1987 that substantial effort was directed towards shrimp in Hawke Channel, so the history of the fishery is very brief. Most of the recent effort occurs in spring just as the ice begins to move out of the area. Catch rates (unstandardized) have increased substantially from 1987 to 1990

but it was not possible to standardize for seasonality and vessel effects. CPUE's for May alone also show an increase from 1988 to 1990. As for the channels to the north, LFD's show a prominent female mode in most years, suggest regular recruitment and do not reflect effects of fishing. Biomass estimates decreased from 1979 to 1981 but there was a large increase between 1985 and 1988 which is difficult to explain in terms growth and recruitment. Immigration seems a more reasonable explanation. Estimates decrease from 1988 to 1990 which does not agree with the commercial CPUE data. Predator/prey interactions are not evident, proportions of maturity stages have been similar for the past three years and less than 50% of females were primiparous. Overall, the resource appears to be healthy with no discernable fishery effects. The only concern is the decrease in biomass from 1988 to 1990.

TAC's for the past two years have been 2000 tons, 500 tons more than the level set for 1987 and 1988. Catches over the past four years have averaged about 2300 t. Since no negative effects are evident from this level of fishing, the TAC's for the next 2 - 3 years could be increased to 2300 tons. It is noted that the Hawke Channel is a large area (3670 sq. n. mi.) - about the size of Hopedale Channel. Even at low densities the area could sustain a large biomass.

ST. ANTHONY BASIN

Although concentrations of shrimp have been known to exist in the St. Anthony Basin for many years, the commercial fleet did not show much interest in the area until 1988 when the catch totalled almost 900 tons. Since then, catches have increased to over 2000 tons in 1990. It is a winter/spring fishery with most effort expended by the end of April. The seasonality of the catch rates is variable and difficult to generalize with the short time series. Catch and unstandardized CPUE's have increased with effort since 1987 and the commercial LFD's do not reflect any response that can be attributed to fishing pressure. Shrimp biomass estimates showed an increase from 1984 to 1985, but no recent survey data area available for comparison with the fishery performance data.

TAC's have been set at 1500 - 1600 tons for the past four years whereas catches have averaged just over 1100 tons annually. Although the available data do not suggest that the fishery has negatively impacted the resource in this area, the catch level of 1600 tons has not been sustained for an extended period. Therefore, the TAC of 1600 tons could be maintained for the next 2 - 3 years to see how and if the resource responds to that exploitation level. It is noted that several of the fishing areas in southern Division 2J and northern 3K are interconnected within the 250 m depth contour. Under certain conditions (i.e. season, temperature) it is possible that migrations of adults occur between these areas. Until the possible relationships between the

shrimp from the different areas are more clearly understood, a cautious approach to exploitation is advisable.

NAFO DIVISION 2G

Despite previous knowledge of shrimp concentrations in NAFO Division 2G, the fishery did not develop until 1988. The season can begin as early as January and last until December. Ice, however, is a limiting factor to the accessability of the grounds and, consequently, the seasonality of the fishery has varied over the three years. The seasonality of shrimp concentrations is also unclear. Best catch rates were attained in different months each year. Over the short series, catch has increased with effort while CPUE's (unstandardized) have decreased. The catch rates for 1989 and 1990 were similar but much lower than the 1988 value. In the latter, effort was confined to two months during which catch rates were extremely high. Catch at length data show increasing proportions of small animals in the catches but the distributions could be affected by the different seasons fished each year. Average length of the female mode has remained constant around 26 mm CL.

Early TAC's in this area (500 tons) were precautionary and recent increases were introduced primarily as an incentive for further development of the fishery. Catch history is short and there are no research biomass estimates to compare with the fishery data. Presently, the Division is split into northern and southern zones with separate TAC's in each (1080 and 1500 tons, respectively). This was done in response to how the fishery developed, starting in a limited area in the north. As effort has spread over the Division, there is no longer a need to segregate. Therefore, advice is provided for the whole area. The average catch from 1988 to 1990 was about 2600 t - the current TAC level. The area is large, about 3400 sq. n. mi. between 180 and 550 m, and has the potential to maintain a high biomass. Catches in the range 2600 - 3000 t could be considered for the next 2 - 3 years to further develop the fishery in this area.

NAFO DIVISION 0B

The occurrence of northern shrimp in NAFO Division 0B east of Cumberland Sound has been known since the mid 1970's but it was long thought that the concentrations were too low to support commercial activity, despite the very large sizes of shrimp found there. In 1988, a few vessels fished the area in October and November, experiencing low catch rates. On December 4, 1988, catch rates increased ten fold and remained variable but high, on average, until ice forced the vessels off the grounds. Consequently, in 1989, much more effort was expended in this area but the catch only exceeded the 1988 catch by 200 t. The fleet was unable to fish the areas where heavy concentrations were encountered the previous year. Anecdotal information indicated

that part of this problem was due to ice in the area. The 1990 data are incomplete but indicate catch rates (in November) approaching 1988 levels. Again, ice was a problem.

The history of the fishery is too short to provide a biological basis for assessing the resource. Catch rates are inconclusive, the area fished has changed each year and the implications of increasing proportions of smaller shrimp in the catches are unclear under these conditions. The average size of females appears to have remained constant at 27 mm CL over the three years.

After the experience of 1988, a precautionary TAC of 3500 tons was implemented for 1989 and 1990. This level has not been achieved in any year. Therefore, within the existing TAC, there is room for expansion of the fishery. This level could be maintained for 2 - 3 years with annual monitoring of the developments.

FUNK ISLAND DEEP

The fishery in this area is also new, beginning in 1988. Catches of about 2000 tons were taken in 1988 and 1989, but dropped to 1200 tons in 1990. CPUE's were similar in 1989 and 1990 but substantially lower than in 1988. The fishing is concentrated in winter and spring with most of the catch taken before June. In each year, the February - April period appears most important. Catch rates show no distinct seasonality in the availability of shrimp except that, from June to December, they tend to be lower. CPUE's are also lower than those obtained in other shrimp fishing areas. Most of the fishing grounds are not accessible during the winter-spring period due to ice and the fleet is often faced with no alternative to the Funk Island Deep. LFD's show that the catches contain a high proportion of small shrimp, especially in 1989 and 1990.

TAC's for the past two years have been set at 1500 t, 500 tons more than the precautionary level advised by CAFSAC in 1989. In practice, this area has been combined with East St. Anthony Basin (see next section) for a TAC of 2000 tons. The average catch over the three years has been approximately 1800 tons. Given the uncertainty of the interrelationships between shrimp concentrations in the southernmost areas (see St. Anthony Basin) and the short time series of fishery data, there is no basis to advise a change in TAC from the current level of 1500 tons.

EAST ST. ANTHONY BASIN

Another area fished in the last three years near the Divisions 2J - 3K boundary is a relatively small depression east of the St. Anthony Basin. The area is defined by the 280 m contour and is shallower than the large basin to the west, the

Funk Island Deep to the south, and the Hawke Channel to the north. For the past four winters, including 1991, the shrimp fleet has fished what appears to be a seasonal concentration of, primarily, berried females. Catch rates are highest in February and March but fluctuate widely on a day to day basis. Vessels stay in the area until catch rates decline to low levels or until the quota is taken (combined in 1989 and 1990 with Funk Island Deep for 2000 tons). Catches from sampling stations in the same area during July research surveys have been very low, supporting the seasonal interpretation. CAFSAC's advice in 1989 was that a TAC of 500 tons from this area would represent a cautious approach to exploitation. Catches from 1988 to 1990 have averaged over 1100 tons with no appreciable change in CPUE's. Commercial LFD's show increasing proportions of small animals in the catches, especially in 1990. But given the high catch rate in the latter, this does not necessarily reflect adverse effects of fishing. In fact, the pattern is very similar to that observed in the Funk Island Deep and, particularly, the St. Anthony Basin where CPUE's have increased since 1987. Therefore, the observed increase in small shrimp could be merely a reflection of improved recruitment.

After heavy fishing pressure in a confined area for several months and seemingly low densities during later months of the year, high concentrations recur each year showing no obvious effects of the previous year's effort. It is likely, although not substantiated, that shrimp migrate from other areas, particularly the St. Anthony Basin. If this is so, then the depths at which shrimp can survive throughout the southern area (Hawke Channel and south) represent a vast habitat, some areas of which support dense concentrations during the winter and spring. A detailed study of the bathymetry in relation to shrimp distribution throughout the southern area is needed to further investigate the relationships between shrimp concentrations.

In 1989, the Invertebrates and Marine Plants Subcommittee held a special meeting to discuss the problems associated with shrimp stock assessment. One important conclusion was that, in general, the effects of fishing are not evident in the existing data base. That conclusion is supported by the findings of this retrospective assessment. It was recommended that experimental areas be defined with no catch controls to see if some response could be elicited. East St. Anthony Basin could be considered for this experiment. Careful consideration should be given to the design of the experiment, ensuring proper controls and monitoring procedures.

PANDALUS MONTAGUI

EASTERN HUDSON STRAIT - UNGAVA BAY

The fishery for Pandalus montagui in eastern Hudson Strait and Ungava Bay began in the late 1970's - early 80's but sustained fishing effort has only occurred since 1986 and only in the former area. Catches in Hudson Strait from 1987 to 1989 averaged about 1100 tons, in line with the existing TAC's. The resource is highly concentrated in August and September when most of the fishing takes place and this is reflected in the CPUE data. Catch rates have ranged between roughly one and two tons per hour except for 1986 - eight tons! The low catch and effort (and possibly CPUE) in 1990 are more likely a reflection of poor market conditions rather than a reflection of a change in stock abundance. Commercial LFD's are inconclusive regarding the effects of the fishery and past research surveys have not defined the distribution of the resource sufficiently to make biomass estimates useful. The area has been recognized as highly dynamic in relation to oceanographic conditions and the shrimp resource as highly variable for which the concept of sustainable yield is not appropriate. The current TAC of 1000 tons appears limiting to the industry in years when market demand for the species exists. Although it is not possible to advise a safe upper level of catch on a biological basis, some prudent increase in the TAC in eastern Hudson Strait for the next 2-3 years could be considered. The overall lack of interest by the fleet and the seemingly sporadic occurrence of concentrations of shirmp in Ungava Bay make the practicality of a 200 ton TAC (or any other arbitrary level) highly questionable. It might be more appropriate to combine the TACs in the two areas for a total of 1,200 t so the fleet can take advantage of whatever concentrations occur from time to time in either area.

Table 1 Northern shrimp fishery data from Hopedale Channel, 1977 - 1990.

			UNSTANDARDIZED			STANDARDIZED		
YEAR	TAC (T)	CATCH[1] (T)	CPUE (KG/H)	INDEX	EFFORT[2] (HR)	CPUE (KG/H)	INDEX	EFFORT[2] (HR)
1977	-	1203	516	1.00	2331	664	1.00	1812
1978	4500	2109	466	0.90	4526	548	0.83	3849
1979	3200	2693	424	0.82	6351	564	0.85	4775
1980	4000	3938	399	0.77	9870	531	0.80	7416
1981	4000	3382	365	0.71	9266	462	0.70	7320
1982	4000	1829	375	0.73	4877	439	0.66	4166
1983	4000	997	299	0.58	3334	339	0.51	2941
1984	3500	712	297	0.58	2397	411	0.62	1732
1985	2800	1687	231	0.45	7303	362	0.55	4660
1986	3400	3498	516	1.00	6779	526	0.79	6650
1987	4000	4538	612	1.19	7415	551	0.83	8236
1988	4000	6584	545	1.06	12081	501	0.75	13142
1989	4400	4329	612	1.19	7074	499	0.75	8675
1990[3]	4400	3900	564	1.09	6915	511	0.77	7632

[1] Catch (tons) from statistics as reported in economic assessment of the northern shrimp fishery.

[2] Effort calculated from catch/CPUE. CPUE calculated from vessel log data.

[3] Preliminary.

Table 2 Biomass estimates (t) and 95% confidence intervals for shrimp in Hopedale Channel, 1979 - 1990.

Year	Mean	Upper	Lower	Area (sq. n. mi.)	No. Sets
1979	18654	34535	2774	2582	56
1980	15386	23890	6881	2991	84
1981	6115	8706	3523	3050	57
1982	12577	16437	8717	3050	77
1983	9178	10756	7601	3359	89
1984	10047	13555	6538	2829	61
1985	13450	21184	5716	3636	65
1986	11138	16020	6257	3494	76
1987	6758	9577	3940	3494	74
1988	9194	12122	6267	3363	71
1989		--- No survey ---			
1990	5636	8354	2918	3693	77

Table 3 Shrimp research survey abundance (n x 10^{-6}) and per cent by sex and maturity stages - Hopedale Channel, 1986 - 1990. PRIMI = Primiparous, MULTI = Multiparous, FE = Females.

	1986		1987		1988		1990	
	N	%	N	%	N	%	N	%
ALL STAGES	1696	100	926	100	1390	100	980	100
MALES	1097	65	514	56	894	64	672	69
PRIMI	230	14	193	21	180	13	166	17
MULTI	369	22	218	24	317	23	133	14
ALL FE	600	35	411	44	496	36	299	31
PRIMI/ALL FE		38		47		36		56

TOTAL MORTALITY[1] (Z):

$Z_{86-87} = 1.01$

$Z_{87-88} = 0.26$

[1] Calculated: $Z = -\ln MULTI_{i+1}/ALL\ FE_i$

Table 4 Northern shrimp fishery data from Cartwright Channel, 1977 - 1990.

YEAR	TAC (T)	CATCH[1] (T)	EST CATCH CAL_YR	UNSTANDARDIZED CPUE (KG/H)	UNSTANDARDIZED INDEX	UNSTANDARDIZED EFFORT[2] (HR)	STANDARDIZED CPUE (KG/H)	STANDARDIZED INDEX	STANDARDIZED EFFORT[2] (HR)
1977	-	1414	1414	599	1.00	2361	536	1.00	2638
1978	800	1521	1521	440	0.73	3457	489	0.91	3110
1979	800	1034	1034	263	0.44	3932	261	0.49	3962
1980	800	170	170	245	0.41	694			
1981	800	67	67	194	0.32	345			
1982	800	154	154	344	0.57	448			
1983	800	3	3	105	0.18	29			
1984	700	290	290	297	0.50	976	221	0.41	1312
1985	770	2	2	63	0.11	32			
1986	1000	1524	1328	587	0.98	2262	753	1.40	1764
1987[3]	800	1456	1418	578	0.96	2453	331	0.62	4284
1988	800	969	1254	1338	2.23	937	754	1.41	1663
1989	1600	1685	1657	848	1.42	1954	734	1.37	2257
1990*	1600	1600	1600	851	1.42	1880	509	0.95	3143

[1] Catch (tons) from statistics as reported in economic assessment of the northern shrimp fishery.

[2] Effort calculated from catch/CPUE. CPUE calculated from vessel log data.

[3] Fishing season changed in 1987, onward, from calendar year to May 1 - April 30, making 1986 a 16 month year (Jan 1, 1986 - April 30, 1987).

* Preliminary.

Table 5 Biomass estimates (t) and 95% confidence intervals for shrimp in Cartwright Channel, 1979 - 1988.

Year	Mean	Upper	Lower	Area (sq. n. mi.)	No. Sets
1979	1886	2871	902	354	24
1980	2783	3413	2152	476	39
1981	2361	3371	1351	563	51
1982	1916	2867	965	505	43
1983[1]	1111	1446	775	871	56
1984	3113	4863	1362	881	47
1985	2574	3524	1625	744	46
1986	1803	2494	1111	878	45
1987	4578	5662	3494	878	43
1988	7258	8753	5763	840	43

[1] Expanded stratified area from 1983 to 1988.

Table 6 Shrimp research survey abundance (n x 10^{-6}) and per cent by sex and maturity stages - Cartwright Channel, 1986 - 1988. PRIMI = Primiparous, MULTI = Multiparous, FE = Females.

	1986		1987		1988	
	N	%	N	%	N	%
ALL STAGES	292	100	766	100	1288	100
MALES	177	61	473	62	798	62
PRIMI	76	26	165	22	227	18
MULTI	39	13	128	17	263	20
ALL FE	115	39	293	38	490	38
PRIMI/ALL FE		67		56		46

TOTAL MORTALITY[1] (Z):

$Z_{86-87} = -0.11$

$Z_{87-88} = 0.11$

[1] Calculated: $Z = -\ln MULTI_{i+1}/ALL\ FE_i$

Table 7 Northern shrimp fishery data from Hawke Channel, 1977 - 1990.

YEAR	TAC (T)	CATCH[1] (T)	EST CATCH CAL_YR	UNSTANDARDIZED CPUE (KG/H)	UNSTANDARDIZED INDEX	UNSTANDARDIZED EFFORT[2] (HR)	STANDARDIZED CPUE (KG/H)	STANDARDIZED INDEX	STANDARDIZED EFFORT[2] (HR)
1977	-	<1	<1	119	0.34	4			
1979	1750	5	5	189	0.54	29			
1981	850	135	135	207	0.59	652	18	0.04	?
1982	850	<1	<1	151	0.43	3			
1986	850	793	0						
1987[3]	1500	2667	1678	353	1.00	4754	475	1.00	3533
1988	1500	1965	3747	784	2.22	4779	285	0.60	13147
1989	2000	2140	1925	1092	3.09	1763	226	0.48	8518
1990*	2000	1600	1815	1427	4.04	1272	398	0.84	4560

[1] Catch (tons) from statistics as reported in economic assessment of the northern shrimp fishery.

[2] Effort calculated from catch/CPUE. CPUE calculated from vessel log data.

[3] Fishing season changed in 1987, onward, from calendar year to May 1 - April 30, making 1986 a 16 month year (Jan 1, 1986 - April 30, 1987).

* Preliminary.

Table 8 Biomass estimates (t) and 95% confidence intervals for shrimp in Hawke Channel, 1979 - 1990.

Year	Mean	Upper	Lower	Area (sq. n. mi.)	No. Sets
1979	4317	5976	2659	3670	41
1980	3842	6916	767	3670	32
1981	807	1493	121	3670	32
1985	2642	4450	835	3670	15
1988[1]	11496	14031	8962	3670	54
1989	6573	8213	4934	3670	56
1990	5308	7512	3103	3670	49

[1]Area stratification revised with new bathymetric data in 1988. Survey results from previous years are post-stratified.

Table 9 Shrimp research survey abundance ($n \times 10^{-6}$) and per cent by sex and maturity stages - Hawke Channel, 1988 - 1990. PRIMI = Primiparous, MULTI = Multiparous, FE = Females.

	1988		1989		1990	
	N	%	N	%	N	%
ALL STAGES	2017	100	1026	100	896	100
MALES	1290	64	573	56	546	61
PRIMI	295	15	136	13	147	16
MULTI	432	21	316	31	203	23
ALL FE	727	36	452	44	350	39
PRIMI/ALL FE		41		30		42

TOTAL MORTALITY[1] (Z):

$Z_{88\text{-}89} = 0.83$

$Z_{89\text{-}90} = 0.80$

[1] Calculated: $Z = -\ln \text{MULTI}_{i+1}/\text{ALL FE}_i$

Table 10 Northern shrimp fishery data from Division 2G, 1980 - 1990.

YEAR	TAC (T)	CATCH[1] (T)	EST CATCH CAL_YR	UNSTANDARDIZED CPUE (KG/H)	UNSTANDARDIZED EFFORT[2] (HR)
1980	500	0	<1	7	7
1982	500	0	<1	108	8
1983	500	30	30	441	68
1987	500	68	0		
1988	500	1640	1083	1831	591
1989	2580	3217	3842	665	5777
1990[3]	2580	2935	2935	712	4122

[1] Catch (tons) from statistics as reported in economic assessment of the northern shrimp fishery.

[2] Effort calculated from catch/CPUE. CPUE calculated from vessel log data.

[3] Preliminary.

Table 11 Northern shrimp fishery data from Division 0B, 1988 - 1990.

YEAR	TAC (T)	CATCH[1] (T)	EST CATCH CAL_YR	UNSTANDARDIZED CPUE (KG/H)	UNSTANDARDIZED EFFORT[2] (HR)
1988	-	2826	2826	584	4839
1989	3500	3039	3039	273	11132
1990[3]	3500	1575	1575	520	3029

[1] Catch (tons) from statistics as reported in economic assessment of the northern shrimp fishery.

[2] Effort calculated from catch/CPUE. CPUE calculated from vessel log data.

[3] Preliminary.

Table 12 Northern shrimp fishery data from St. Anthony Basin, 1977 - 1990.

YEAR	TAC (T)	CATCH[1] (T)	EST CATCH CAL_YR	UNSTANDARDIZED CPUE (KG/H)	UNSTANDARDIZED EFFORT[2] (HR)
1977	-	0	<1	114	2
1986	1200	48	0	-	-
1987[3]	1500	922	167	234	714
1988	1500	1385	873	478	1826
1989	1600	1536	1389	537	2587
1990*	1600	571	2033	579	3511

[1] Catch (tons) from statistics as reported in economic assessment of the northern shrimp fishery.

[2] Effort calculated from catch/CPUE. CPUE calculated from vessel log data.

[3] Fishing season changed in 1987, onward, from calendar year to May 1 - April 30, making 1986 a 16 month year (Jan 1, 1986 - April 30, 1987).

* Preliminary.

Table 13 Biomass estimates (t) and 95% confidence intervals for shrimp, Greenland halibut and cod in St. Anthony Basin, 1981 - 1985.

Year	Species	Mean	Upper	Lower	Area (sq. n. mi.)	No. Sets
1981	Shrimp	2776	4909	642	1372	12
	Turbot	761	1700	-		
	Cod	142	273	101		
1984	Shrimp	2840	5119	561	1372	18
	Turbot	11252	18560	3945		
	Cod	7528	18395	-		
1985	Shrimp	4150	6415	1884	1372	30
	Turbot	6335	8445	4225		
	Cod	770	1198	342		

Table 14 Northern shrimp fishery data from Funk Island Deep, 1988 - 1990.

YEAR	TAC[1] (T)	EST CATCH CAL_YR[2]	UNSTANDARDIZED CPUE (KG/H)	UNSTANDARDIZED EFFORT (HR)
1988	-	1965	425	4626
1989	1500	2172	269	8080
1990	1500	1192	279	4279

[1] The TAC for this area (1500 t) was combined with the 500 t TAC for East St. Anthony Basin for a total TAC of 2000 t.

[2] Catch (t) estimated from log book data. Official catch statistics not available.

Table 15 Northern shrimp fishery data from East St. Anthony Basin, 1988 - 1990.

YEAR	TAC[1] (T)	EST CATCH CAL_YR[2]	UNSTANDARDIZED CPUE (KG/H)	UNSTANDARDIZED EFFORT (HR)
1988	-	1264	509	2484
1989	500	1246	424	2940
1990	500	897	517	1733

[1] The TAC for this area (500 t) was combined with the 1500 t TAC for the Funk Island Deep for a total TAC of 2000 t.

[2] Catch (t) estimated from log book data. Official catch statistics not available.

Table 16 Pandalus montagui fishery data from Hudson Strait, 1979 - 1990.

YEAR	TAC (T)	CATCH[1] (T)	EST CATCH CAL_YR	UNSTANDARDIZED CPUE (KG/H)	UNSTANDARDIZED EFFORT[2] (HR)
1979	-	92	92	-	-
1980	100	236	236	-	-
1981	100	9	9	1100	8
1986	750	377	377	8118	46
1987	1000	1057	1057	1729	611
1988	1000	1124	1124	1579	712
1989	1000	1118	1118	1650	678
1990[3]	1000	163	163	924	176

[1] Catch (tons) from statistics as reported in economic assessment of the northern shrimp fishery.

[2] Effort calculated from catch/CPUE. CPUE calculated from vessel log data.

[3] Preliminary.

Table 17 Pandalus montagui fishery data from Ungava Bay, 1981 - 1989.

YEAR	TAC (T)	CATCH[1] (T)	EST CATCH CAL_YR	UNSTANDARDIZED CPUE (KG/H)	UNSTANDARDIZED EFFORT[2] (HR)
1981	100	4	4	-	-
1986	100	99	99	-	-
1987	200	12	12	-	-
1989	200	151	151	-	-

[1] Catch (tons) from statistics as reported in economic assessment of the northern shrimp fishery.

[2] Effort calculated from catch/CPUE. CPUE calculated from vessel log data.

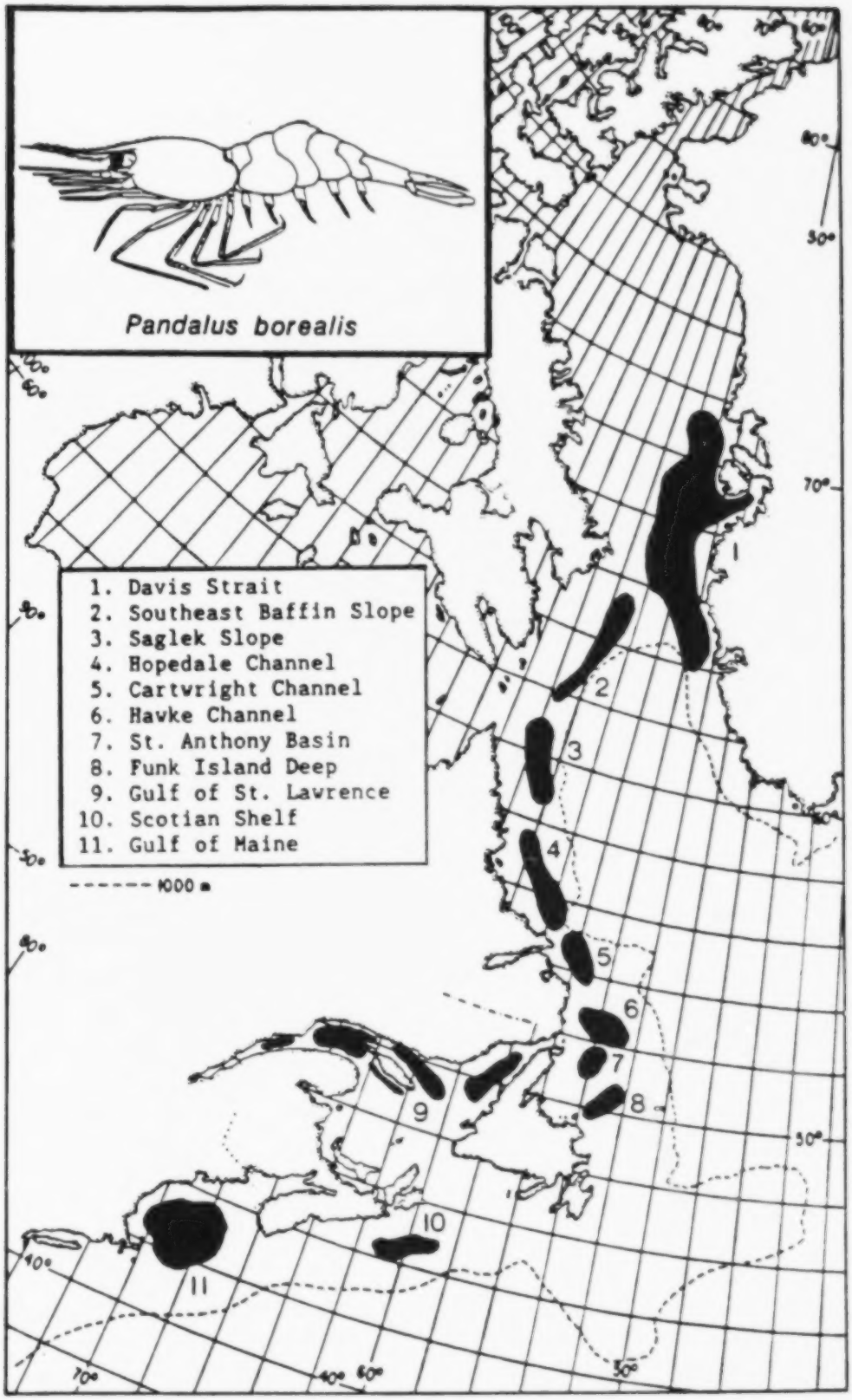


Fig.1. Shrimp fishing areas of the Northwest Atlantic.

Fig 2 Shrimp Catch (T.) from Hopedale Channel 1977 - 1990

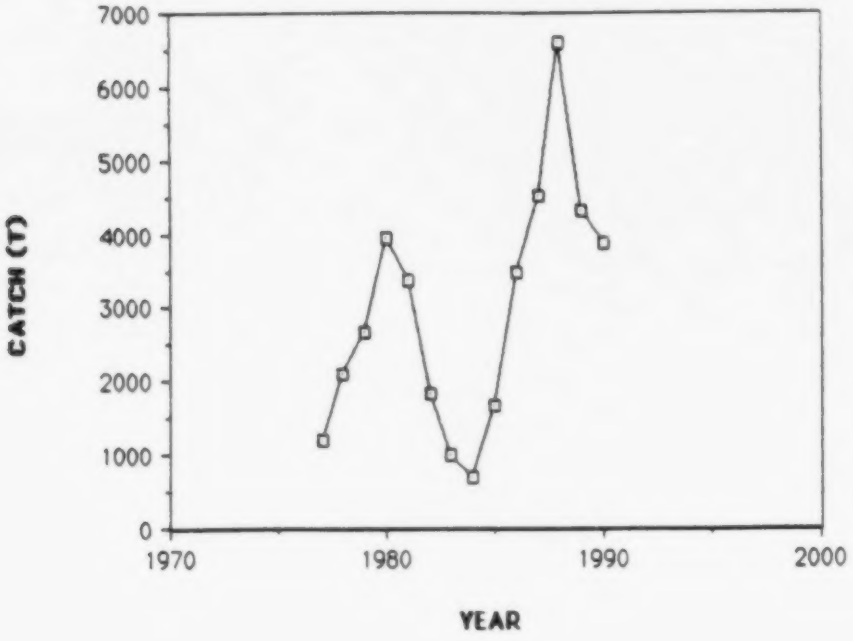


Fig 3 Catch per hour - Hopedale Channel, 1977 - 1990.

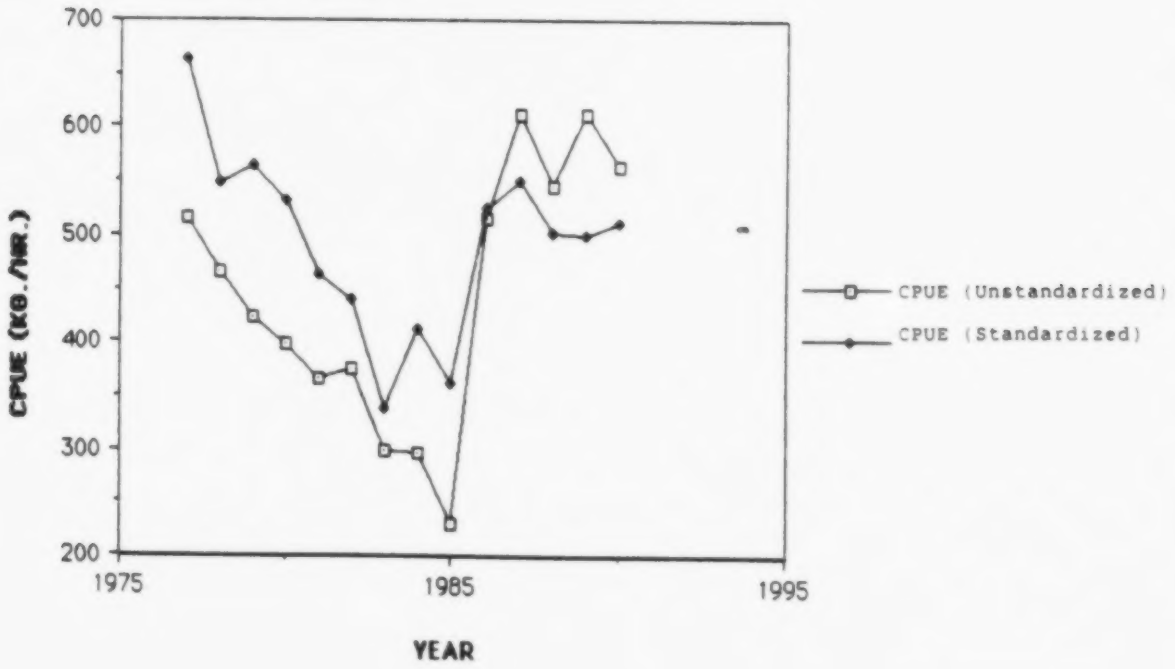


Fig. 4 Catch at length ____ vs Abundance at length ---
Hopedale Channel (1979-88).

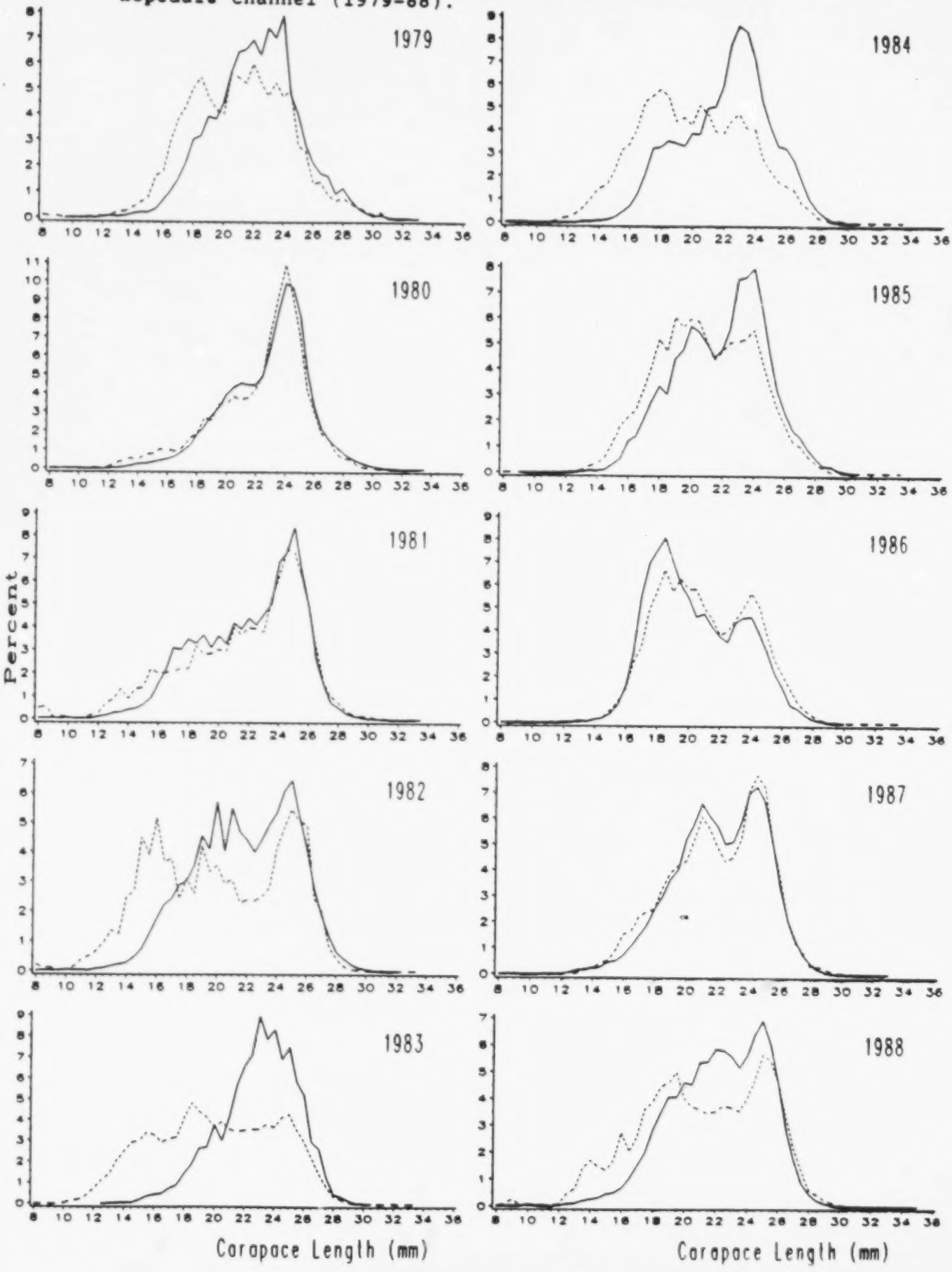


Fig. 5

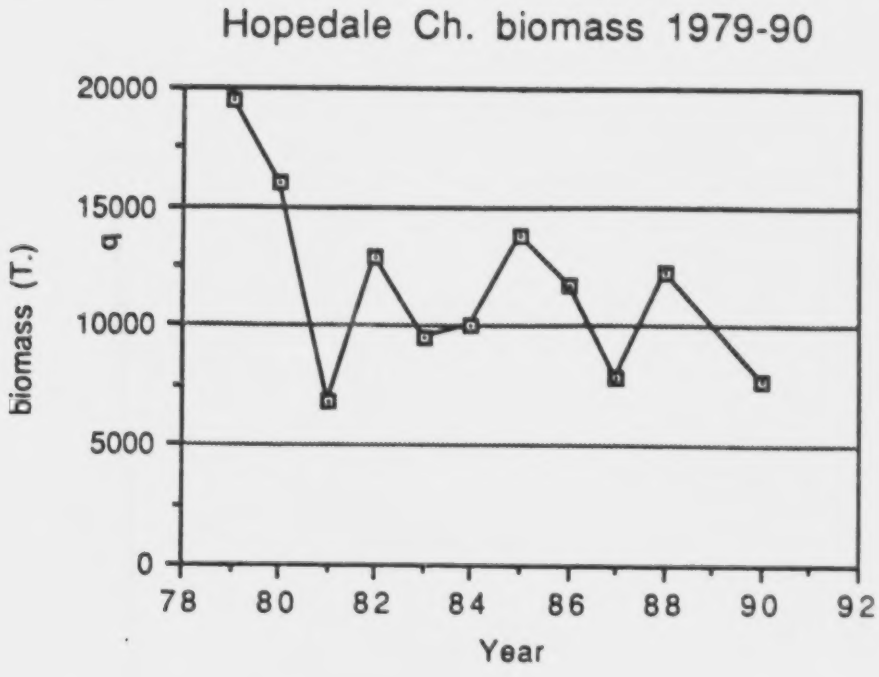


Fig 6 **Shrimp catch versus standardized fishing effort - Hopedale Channel, 1977 - 1990.**

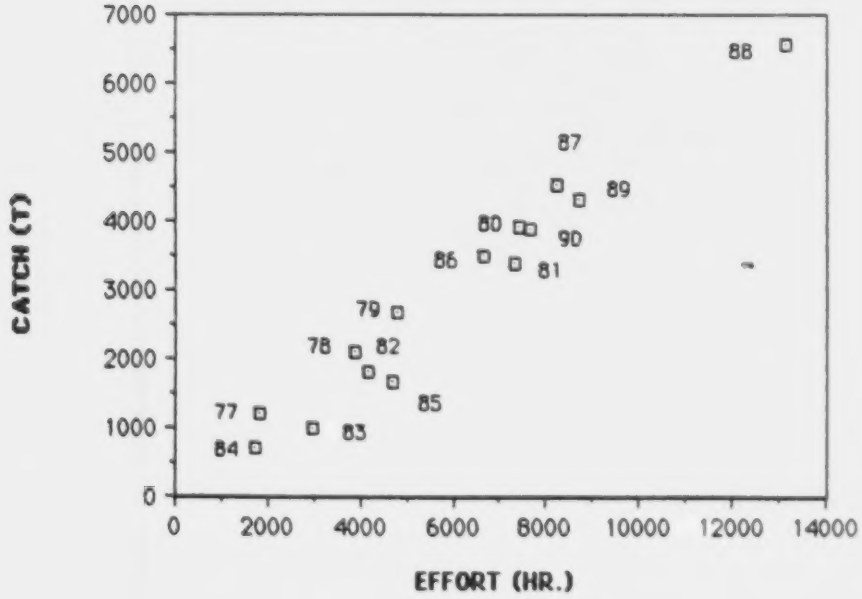


Fig. 7 . Shrimp CPUE verses effort (unstandardized) Hopedale Channel, 1977 - 1990.

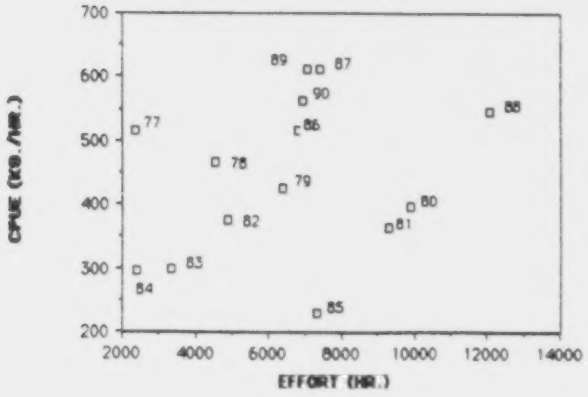


Fig. 8 Percent females in year i+1 versus catch - Hopedale Channel, 1977 - 1988.

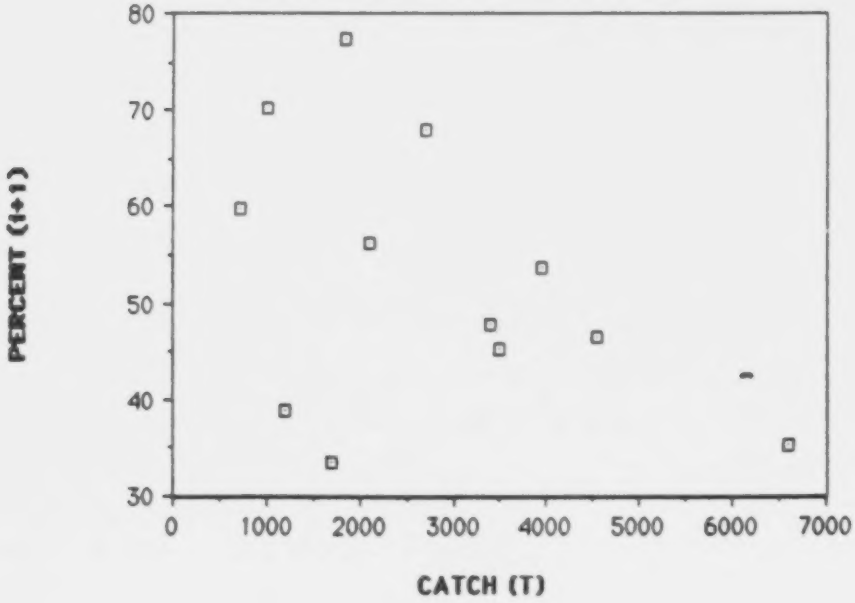


Fig. 9a Unstandardized CPUE versus biomass - Hopedale Channel, 1979 - 1990.

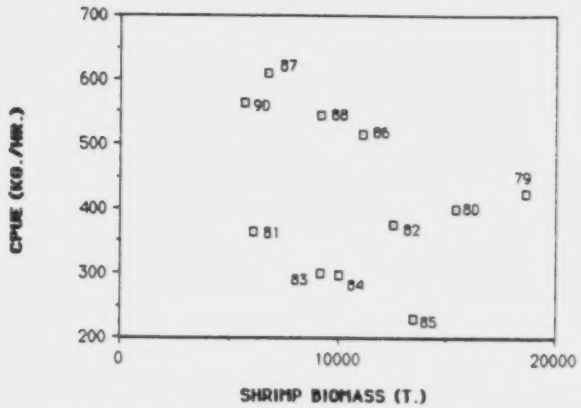


Fig. 9b Standardized CPUE versus biomass - Hopedale Channel, 1979 - 1990.

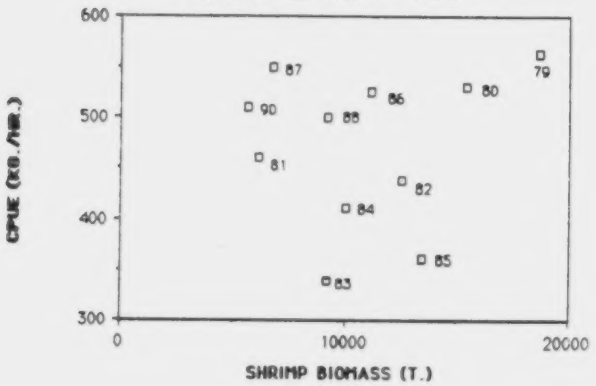


Fig. 10 Shrimp biomass (yr. i+1) versus catch (yr. i) - Hopedale Channel, 1978 - 1989.

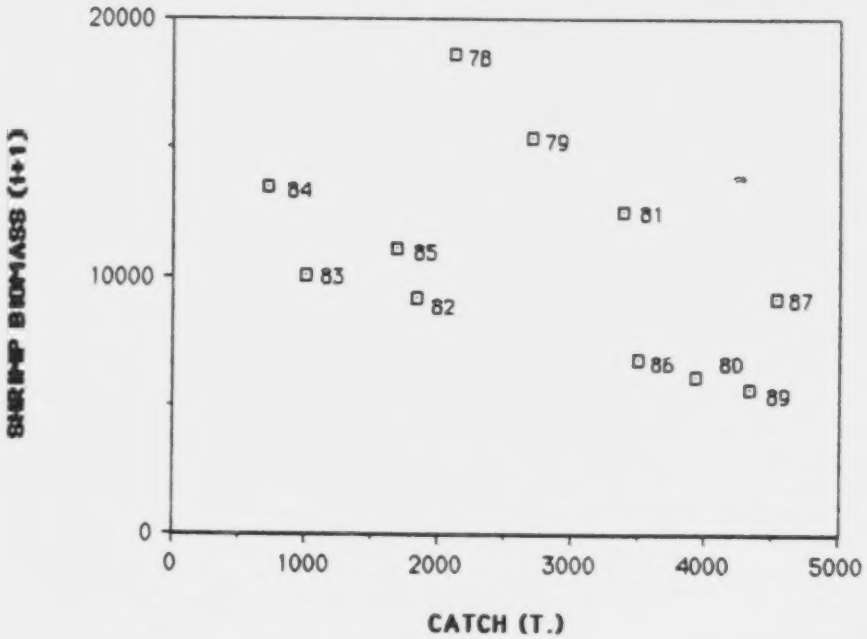


Fig. 11a **Shrimp biomass versus Greenland halibut biomass - Hopedale Channel, 1979 - 1990.**

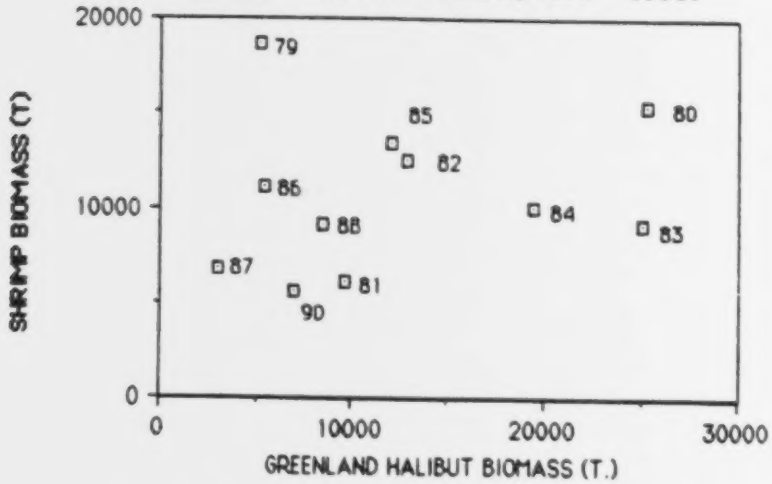


Fig. 11b **Shrimp biomass versus cod biomass - Hopedale Channel, 1979 - 1990.**

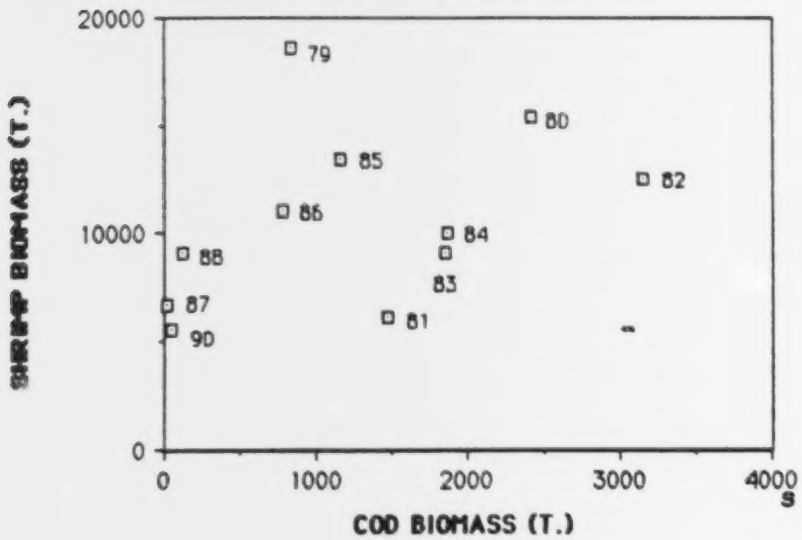


Fig. 12 Shrimp catch (T.) from Cartwright Channel, 1977 - 1990.

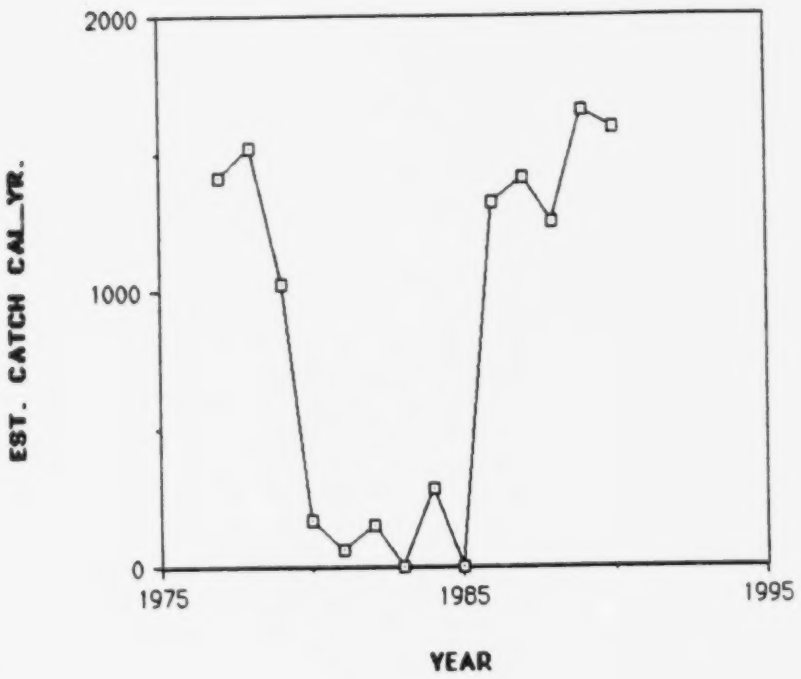


Fig.13 Catch at length ____ vs Abundance at length ----
Cartwright Channel (1979-88).

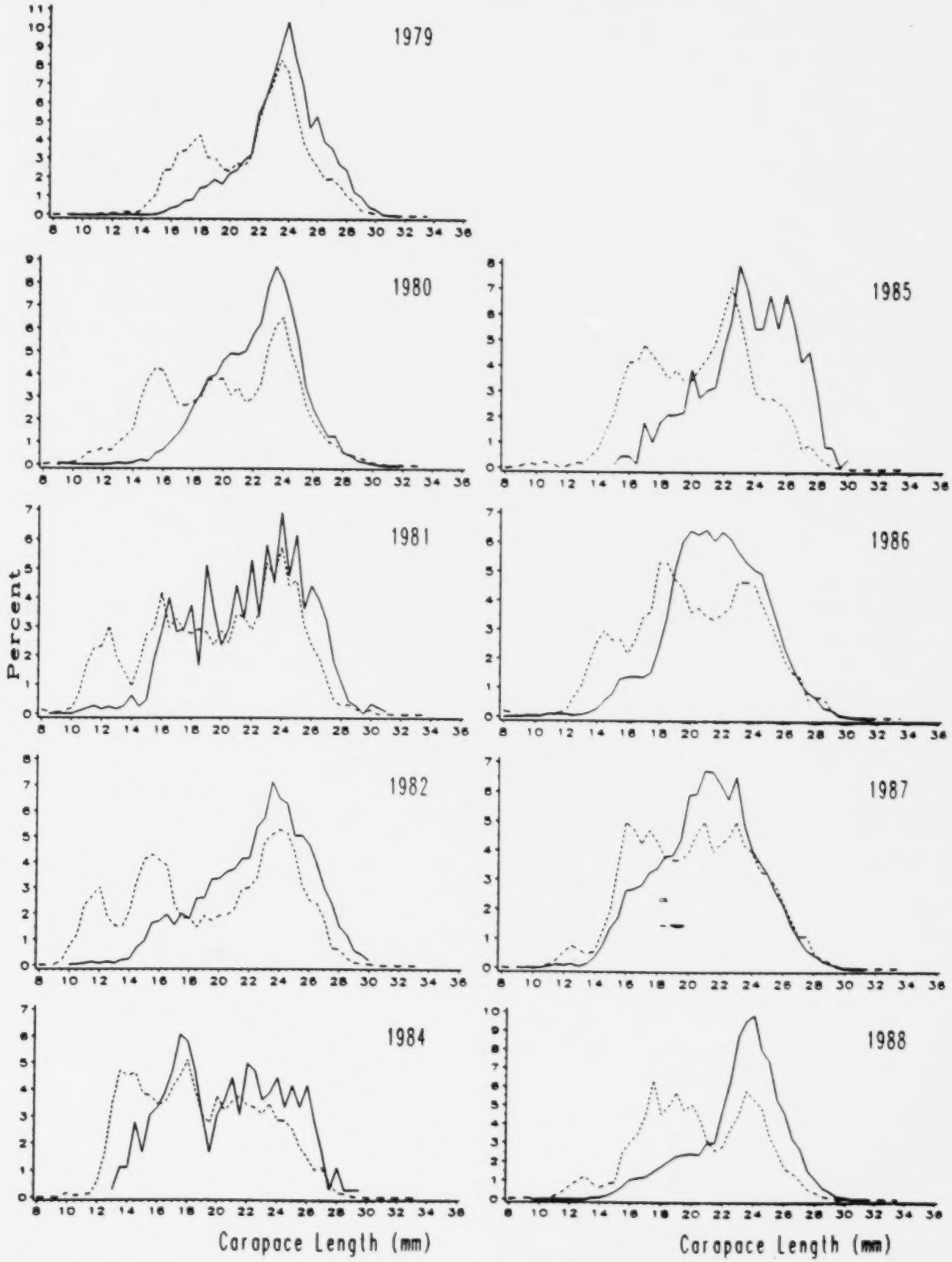


Fig.14 **Minimum trawlable biomass (T.) from stratified surveys - Cartwright Channel, 1979 - 1990.**

Fig 15a **Shrimp catch versus effort (unstandardized) - Cartwright Channel, 1977 - 1990.**

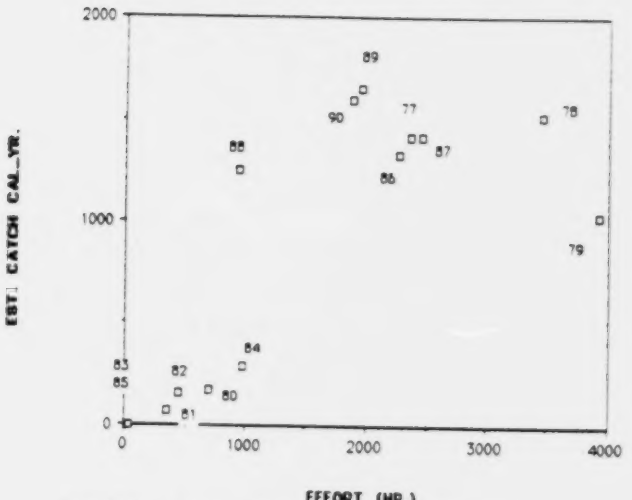


Fig 15b **Shrimp catch versus effort (standardized) - Cartwright Channel, 1977 - 1990.**

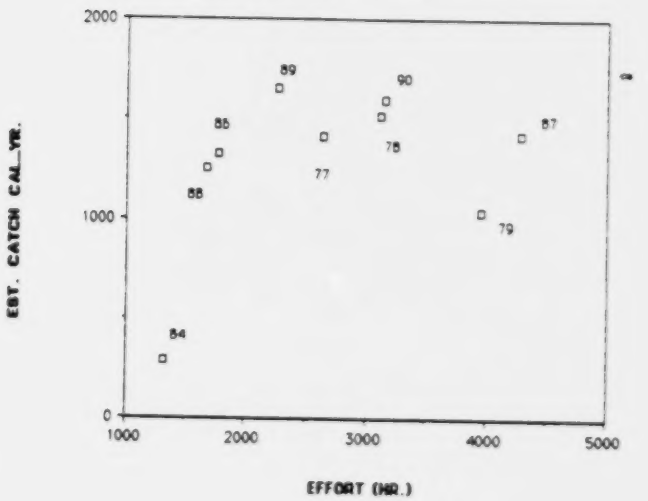


Fig. 16a Shrimp CPUE (standardized) versus effort (unstandardized) - Carlwright Channel, 1977 - 1990.

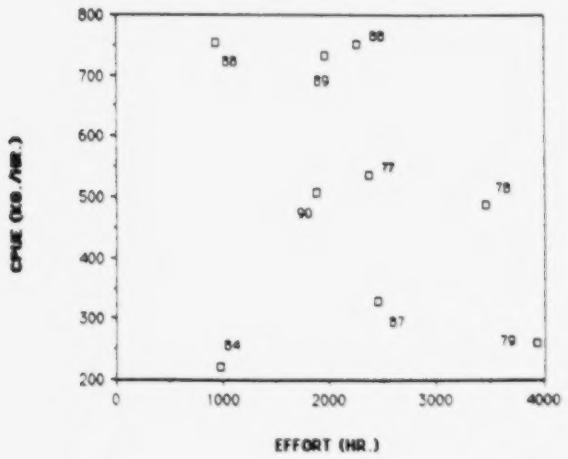


Fig 16b Shrimp CPUE (standardized) versus effort (standardized) - Carlwright Channel, 1977 - 1990.

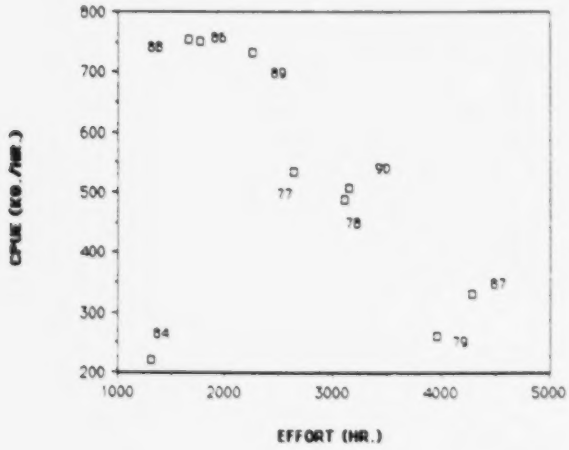


Fig 16c Shrimp CPUE (unstandardized) versus effort (unstandardized) - Carlwright Channel, 1977 - 1990.

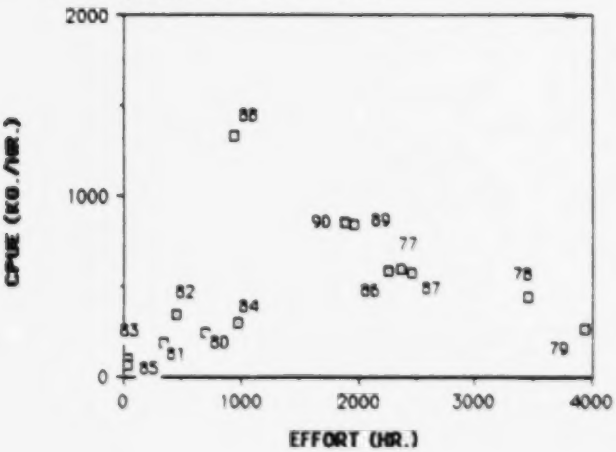


Fig.17a Shrimp CPUE (unstandardized) versus shrimp density - Cartwright Channel, 1979 - 1988.

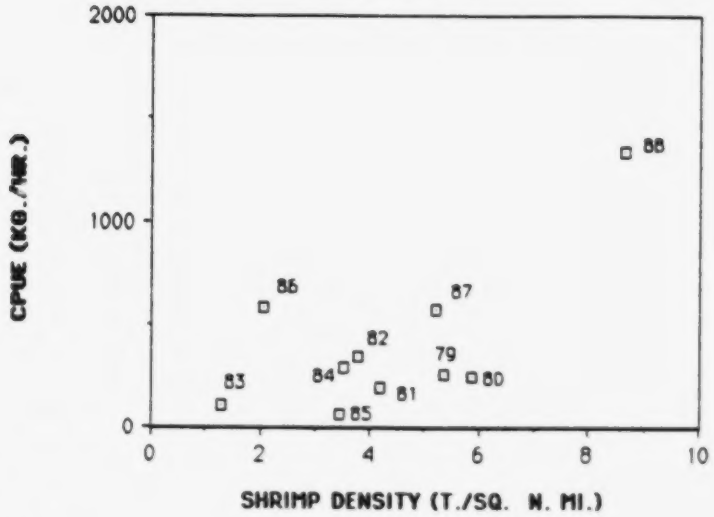


Fig.17b Shrimp CPUE (standardized) versus shrimp density - Cartwright Channel, 1979 - 1990.

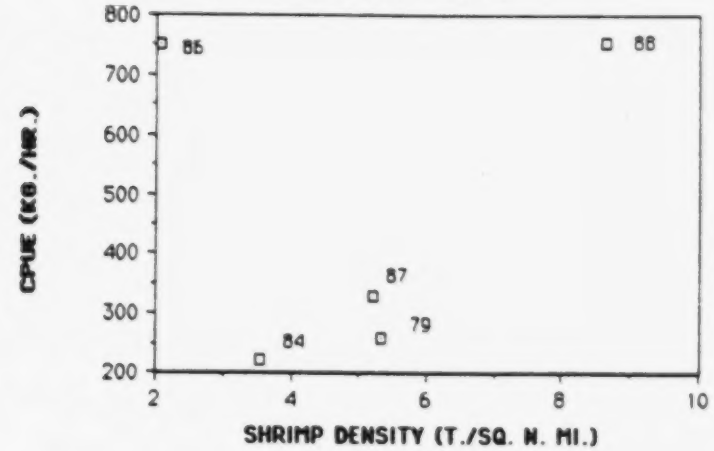


Fig 18 Shrimp density (yr. i+1) versus catch (yr. i) - Cartwright Channel, 1978 - 1987.

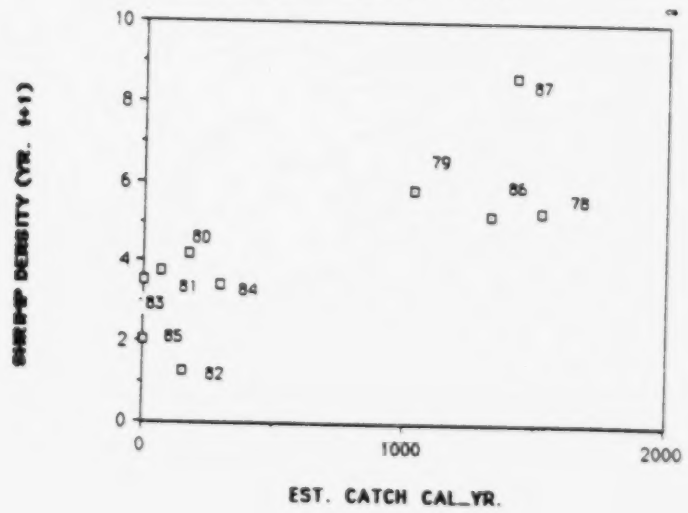


Fig. 19a Shrimp density versus Greenland halibut density - Cartwright Channel, 1979 - 1990.

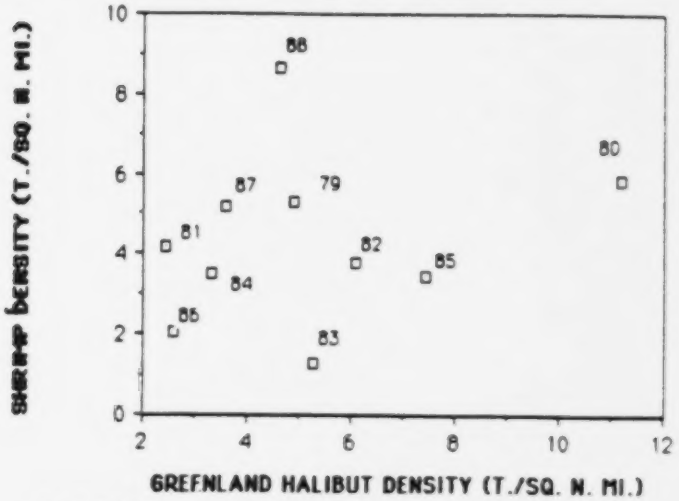


Fig 19b Shrimp density versus cod density - Cartwright Channel, 1979 - 1988.

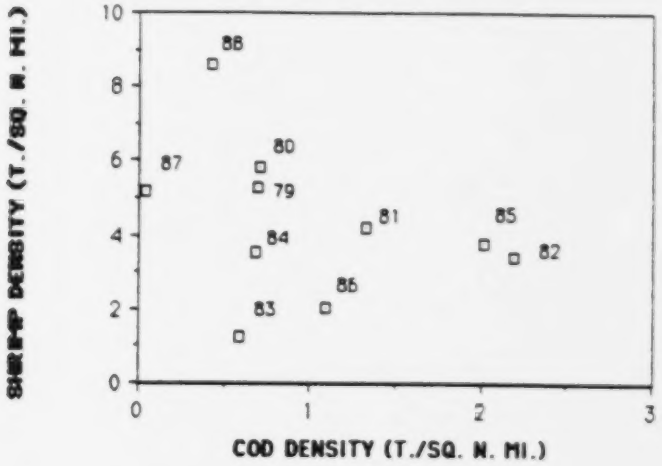


Fig 19c Mean number of 1+ cod per tow from 2J fall surveys versus shrimp biomass - Cartwright Channel, 1979 - 1988.

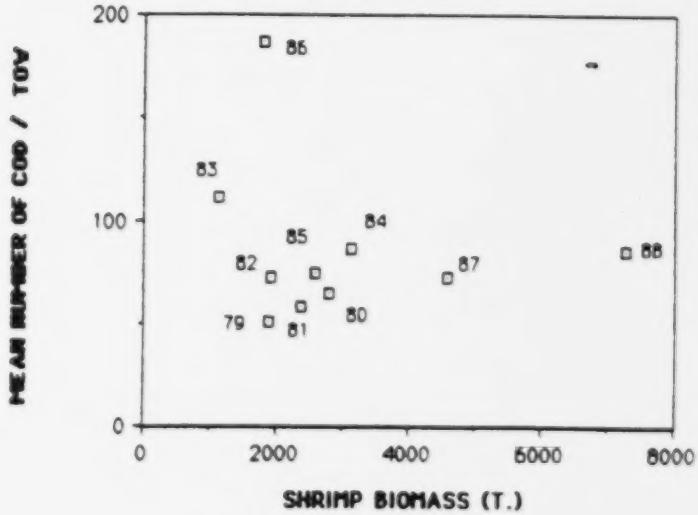
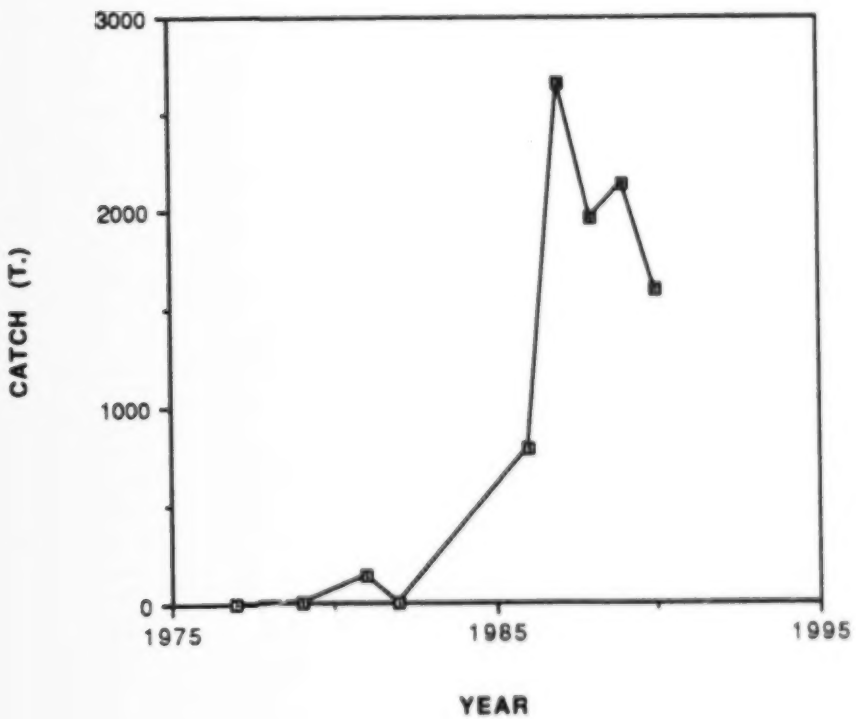


Fig 20 Catch versus year - Hawke Channel, 1977 - 1990.



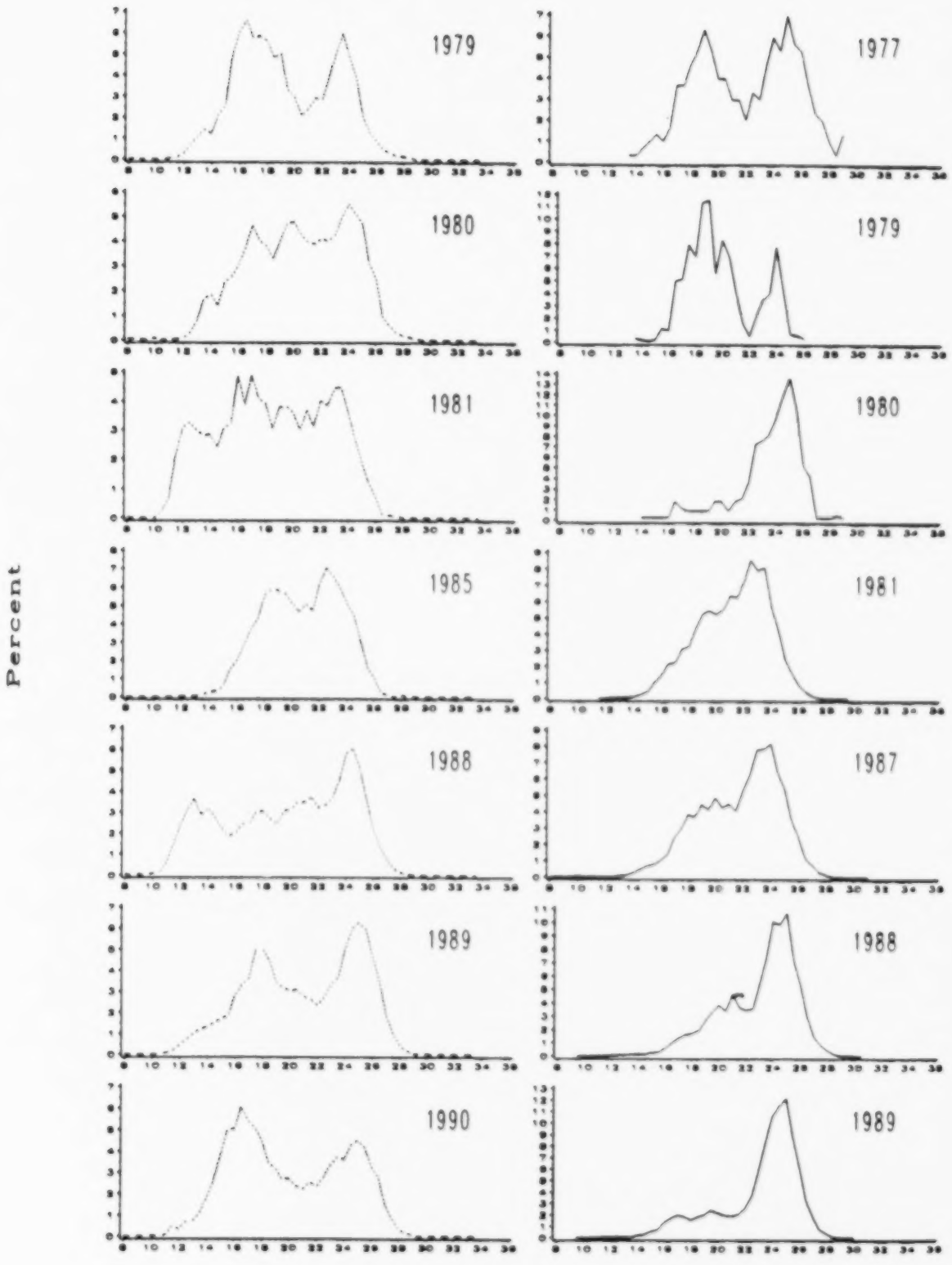


Fig. 21 Abundance at length from research surveys - Hawke Channel (1979-90).

Commercial catch at length - Hawke Channel (1977-89).

Fig 22a Catch versus effort (unstandardized) - Hawke Channel, 1977 - 1990.

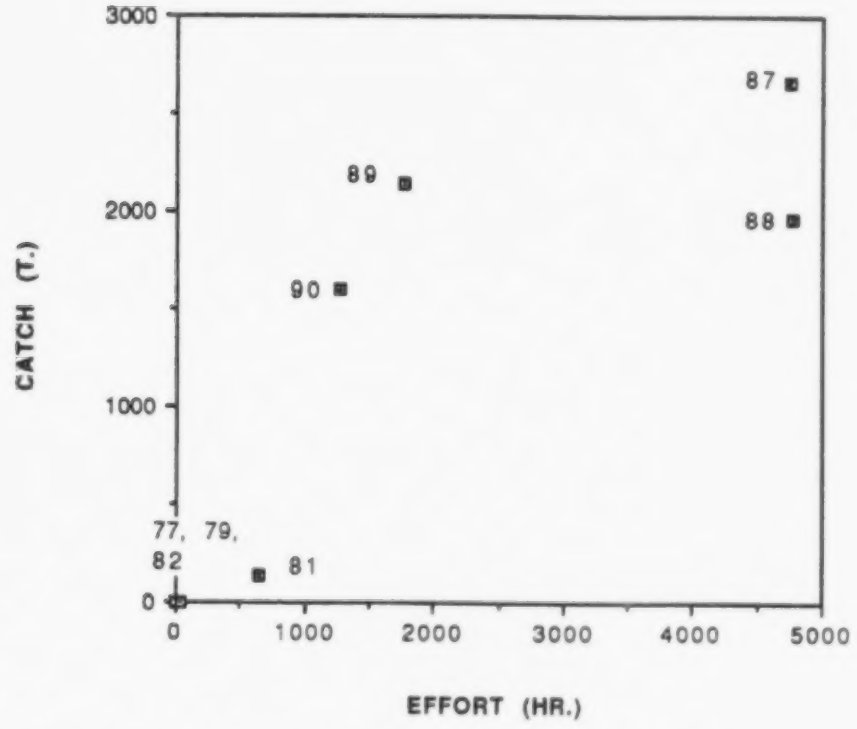


Fig 22b CPUE (unstandardized) versus effort (unstandardized) - Hawke Channel, 1977 - 1990.

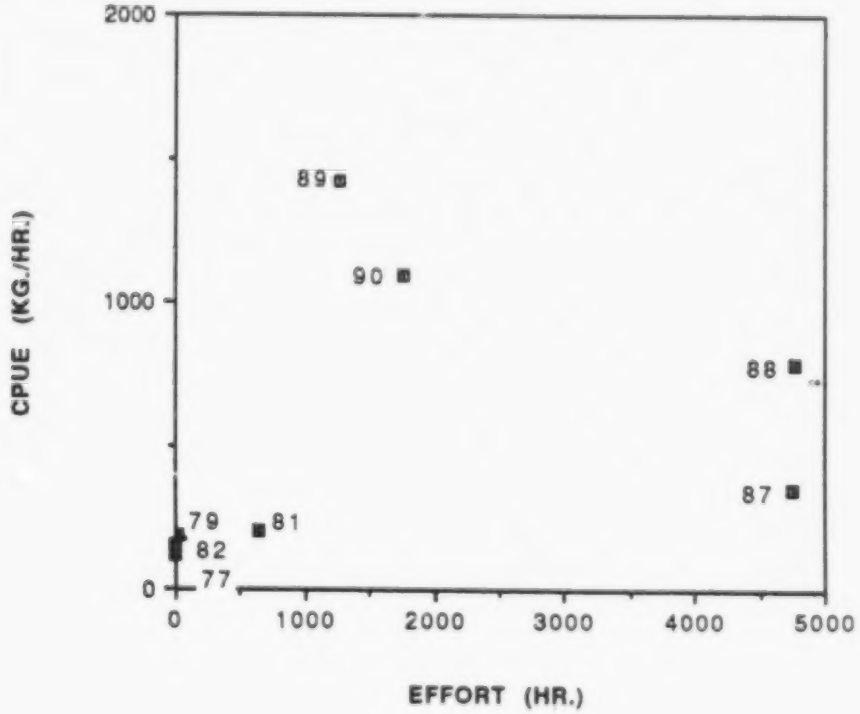


Fig 23a Biomass versus year - Hawke Channel, 1979 - 1990.

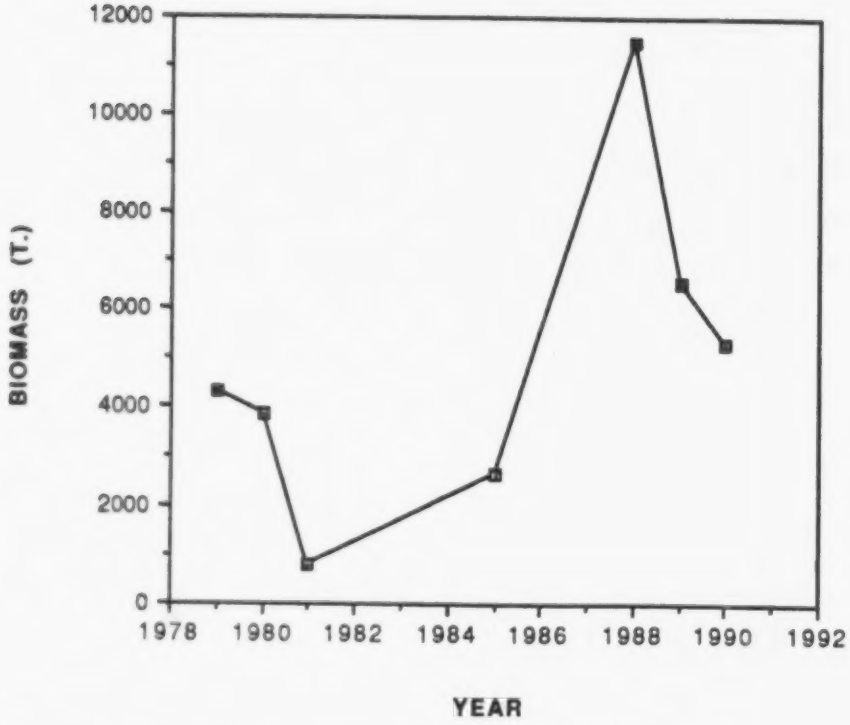


Fig 23b CPUE versus biomass - Hawke Channel, 1979 - 1990.

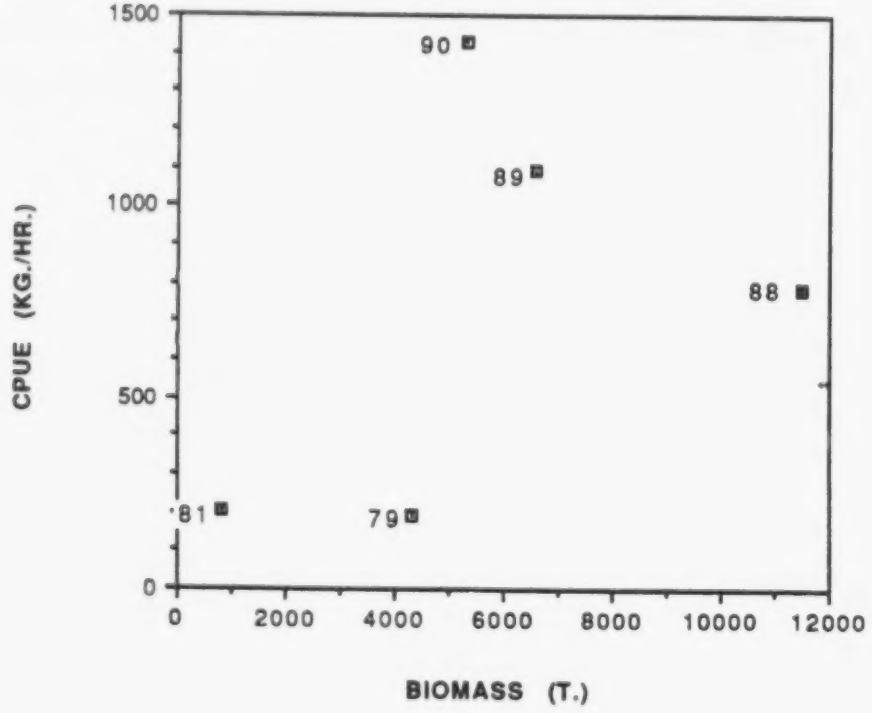


Fig. 24 a Shrimp biomass versus Greenland Halibut biomass - Hawke Channel, 1979 - 1990.

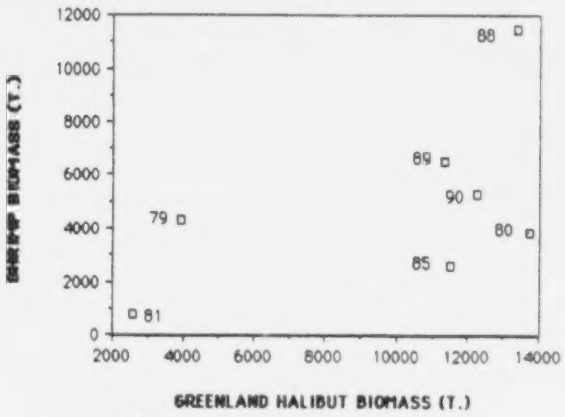


Fig 24 b Shrimp biomass versus cod biomass - Hawke Channel, 1979 - 1990.

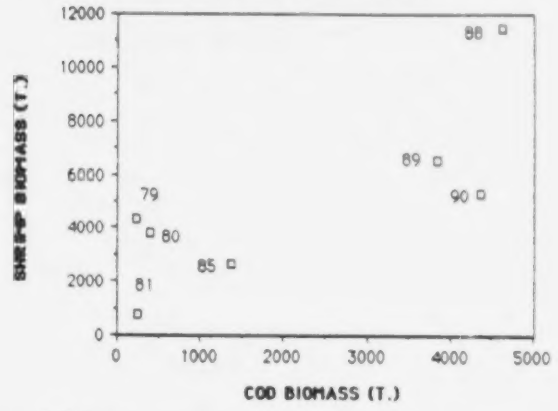
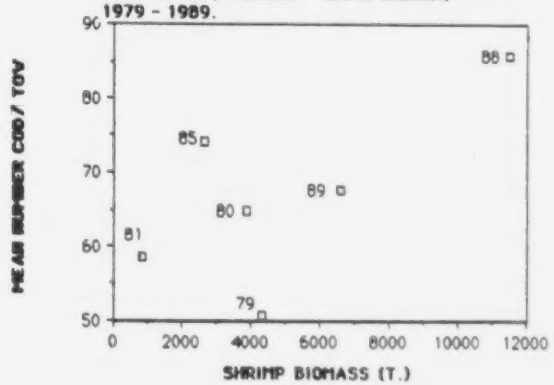


Fig 24 c Mean number 1+ cod per tow from 2J fall surveys versus shrimp biomass - Hawke Channel, 1979 - 1989.



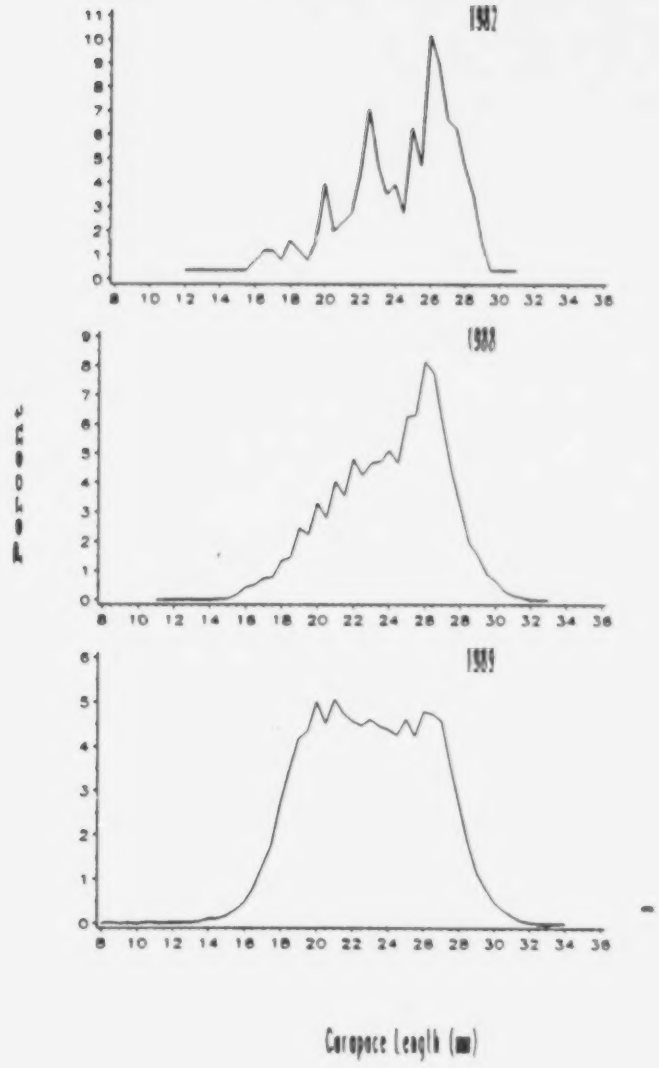


Fig 25 Commercial catch at length - Division 2G (1982-89).

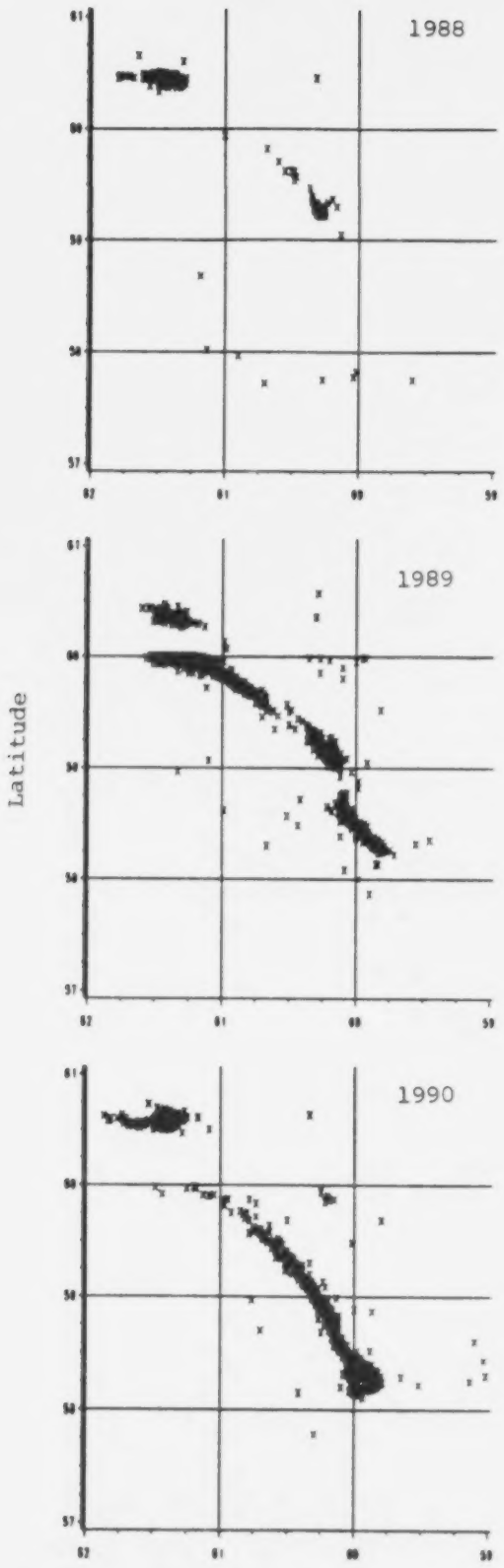


Fig 26 Fishing areas in Div. 2G, 1988-90.

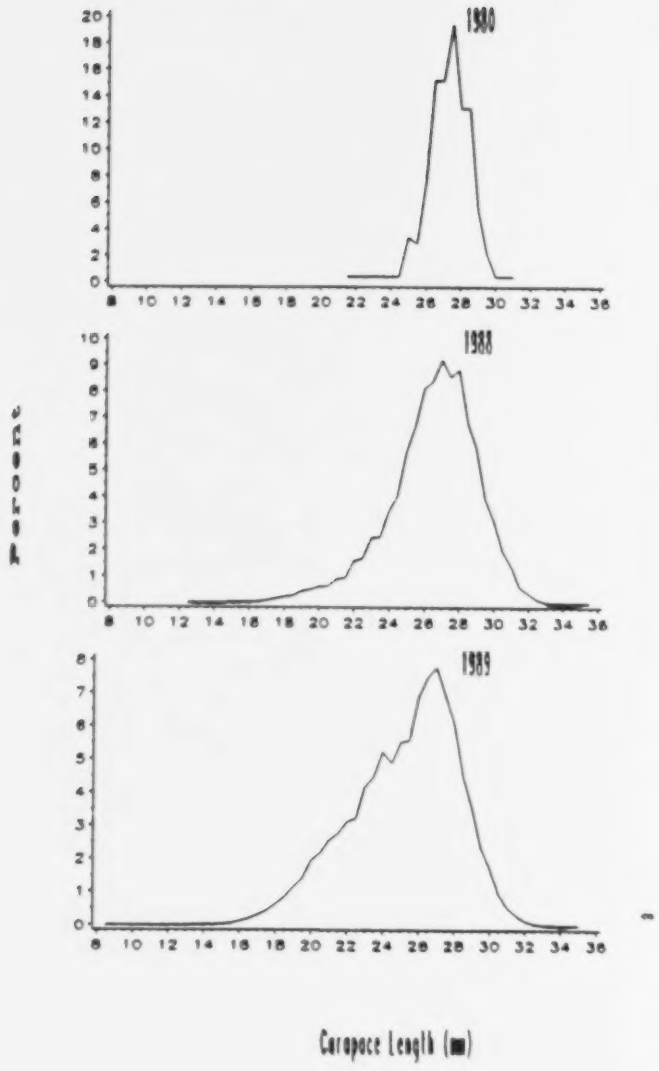


Fig 27 Commercial catch at length - Division 0B (1980-89).

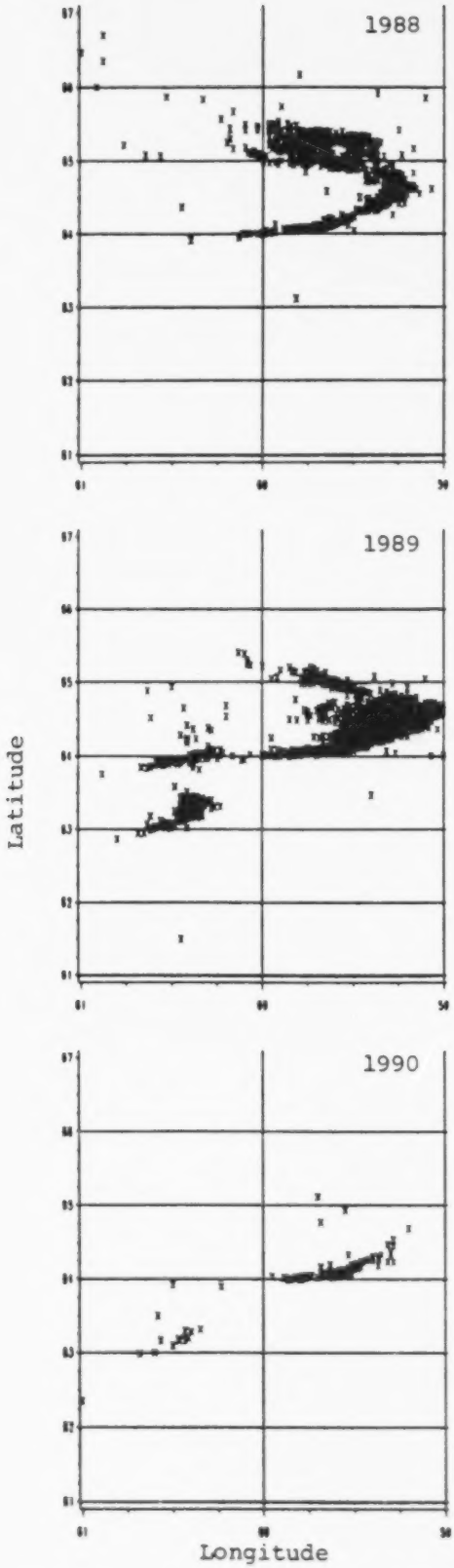


Fig 28 Fishing areas in Div. 0B, 1988-90.

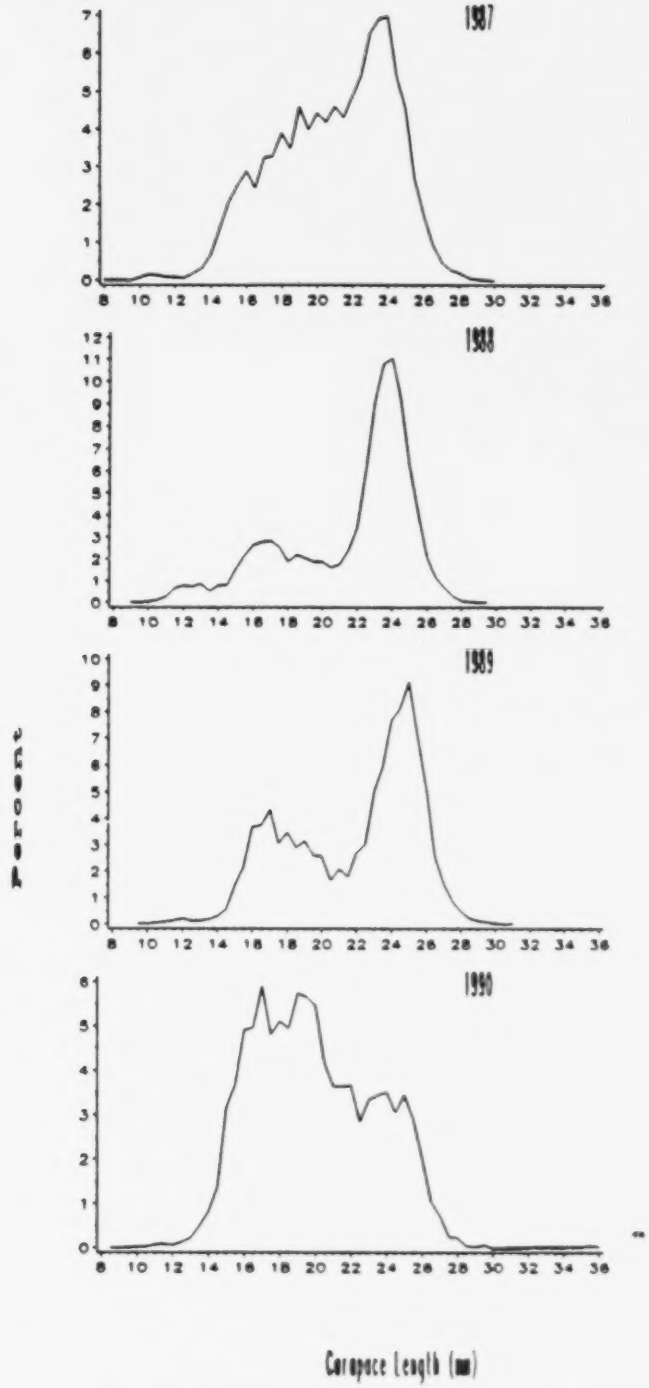


Fig 29 Commercial length frequencies St. Anthony Basin (1987-90).

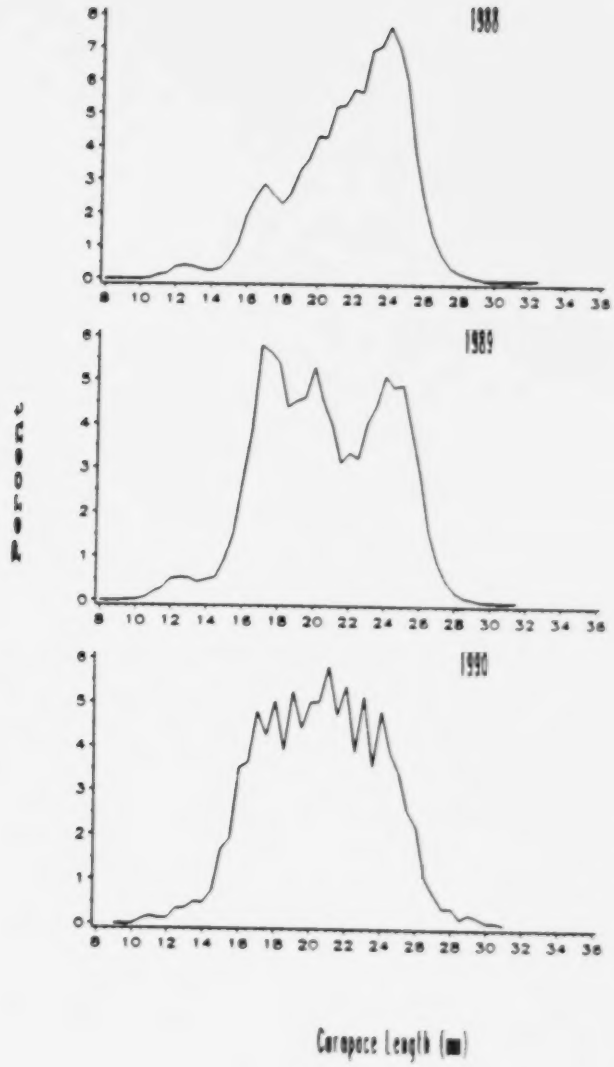


Fig 30 Commercial length frequencies Funk Island Deep (1988-90).

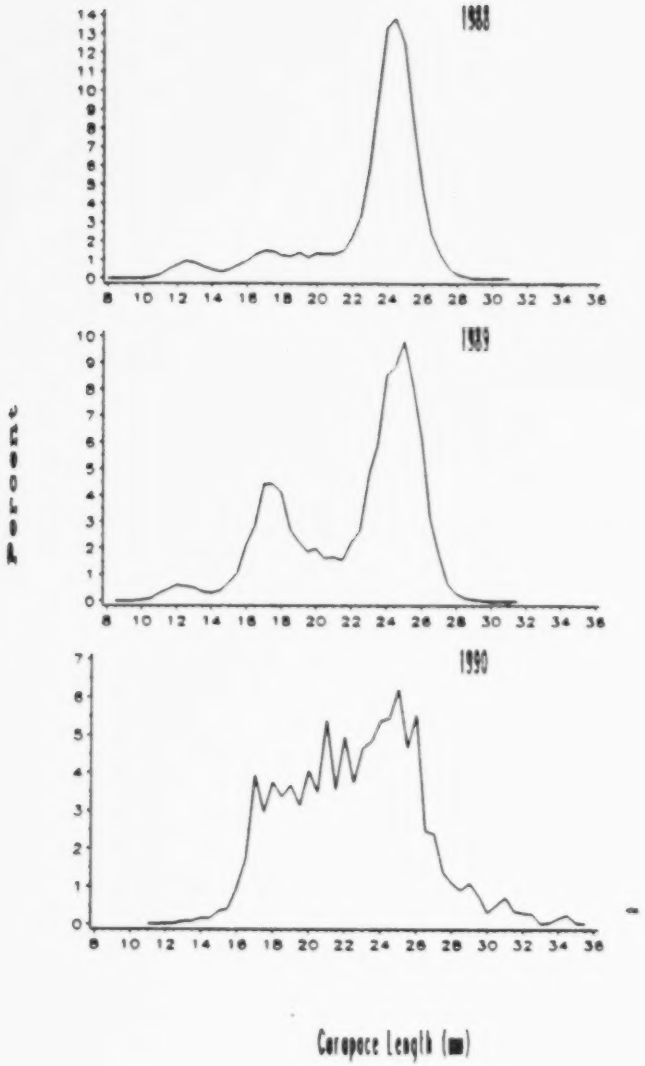


Fig 31 Commercial length frequencies East St. Anthony Basin (1988-90).

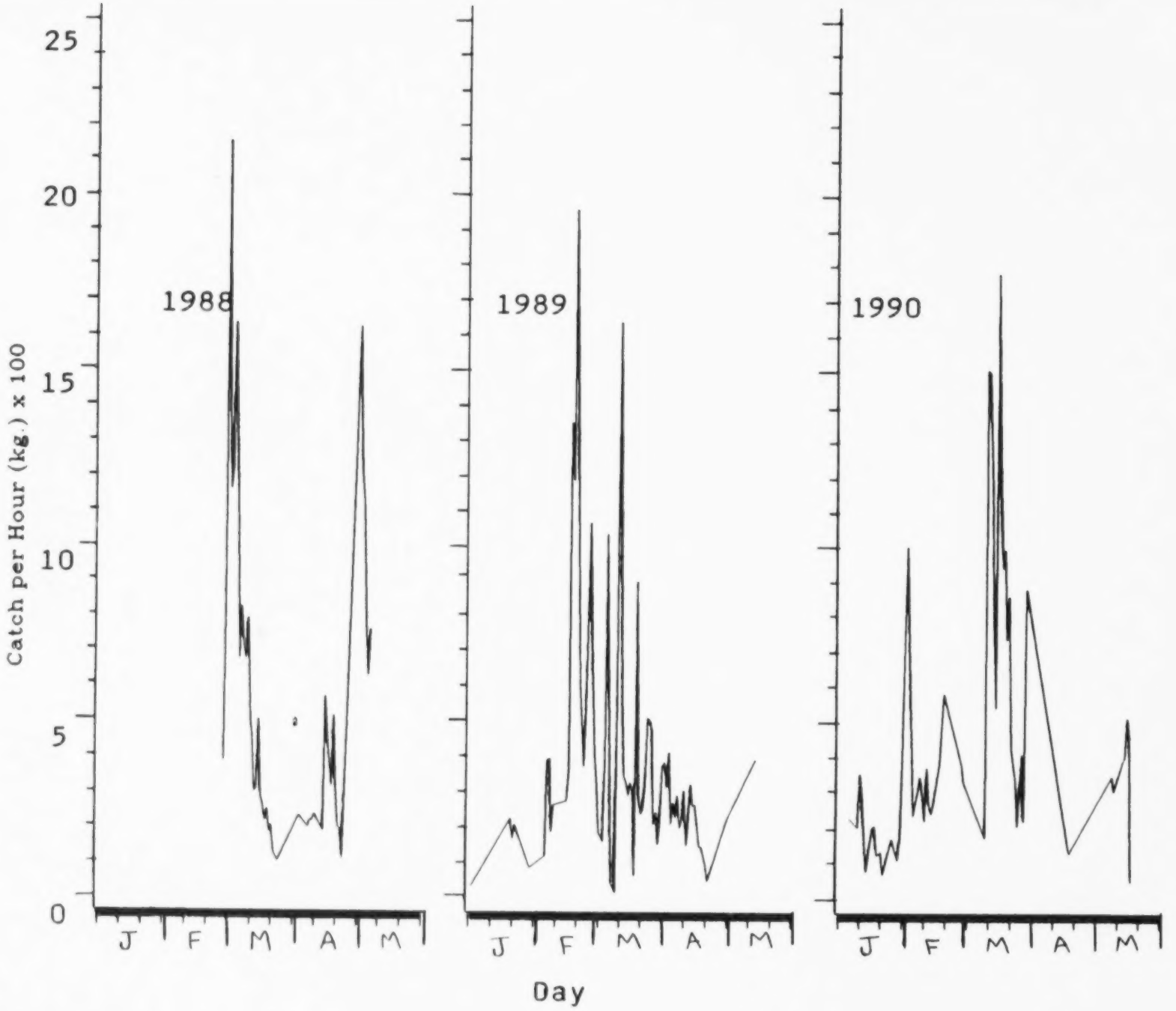


Fig 32 (1988-90) Catch per unit effort by day-East St. Anthony Basin

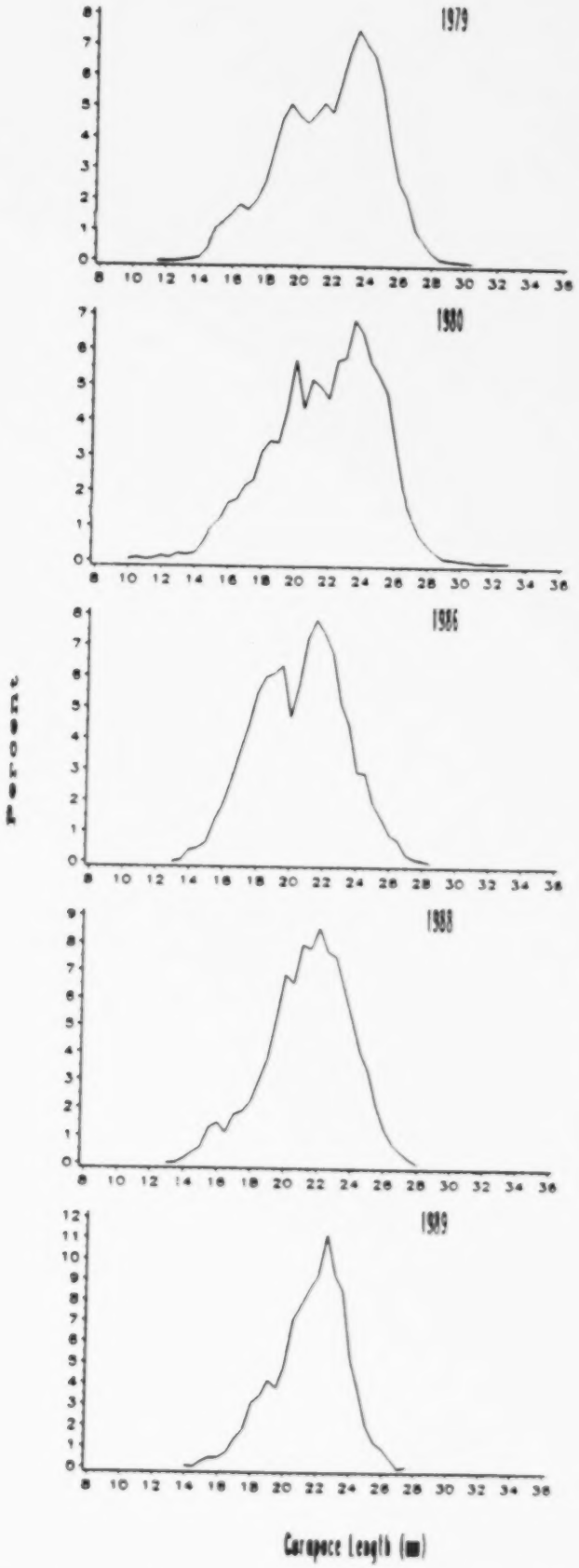


Fig 33 Commercial catch at length - Hudson Strait (1979-89)

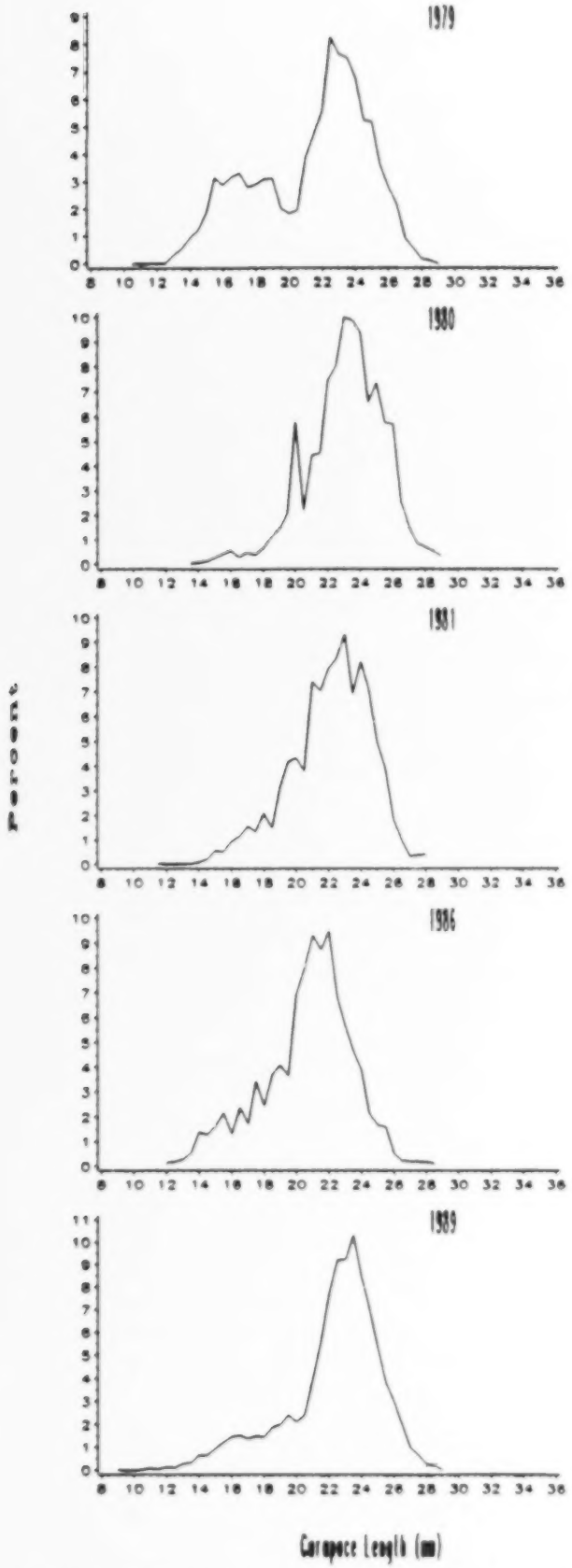


Fig 34 Commercial catch at length - Ungava Bay (1979-89)